AD-A129 165 IMPLEMENTATION OF A BIOMASS ENERGY ISLAND FOR A FORESTED AIR FORCE INSTALLATION(U) ULTRASYSTEMS INC FAIRFAX VA W J HUFF ET AL. JAN 83 AFESC/ESL-TR-83-04 1/1

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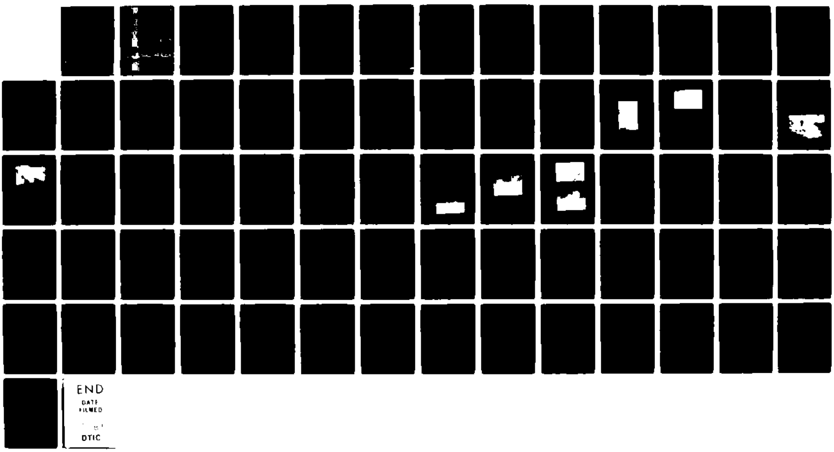

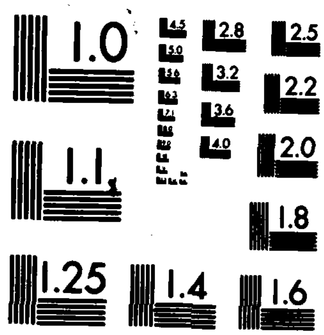
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ESL-TR-83-04

IMPLEMENTATION OF A BIOMASS ENERGY ISLAND FOR A FORESTED AIR FORCE INSTALLATION

AD A129165

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JANUARY 1983

FINAL REPORT
MARCH 1982 - JANUARY 1983

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ESL-TR-83-04	2. GOVT ACCESSION NO. AD-A129165	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Implementation of a Biomass Energy Island for a Forested Air Force Installation		5. TYPE OF REPORT & PERIOD COVERED Final Report March 1982 - January 1983
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) W. J. Huff, W. V. McConnell, P. E. Steadman		8. CONTRACT OR GRANT NUMBER(s) USAF MIPR N-82-11
9. PERFORMING ORGANIZATION NAME AND ADDRESS ULTRASYSTEMS, INC. Eastern Operations 10340 Democracy Lane, Fairfax, Virginia 22030		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program Element 64708F JON: 20545024
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Engineering and Services Center HQ AFESC/RDCS Tyndall AFB FL 32403		12. REPORT DATE January 1983
		13. NUMBER OF PAGES 65
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) U.S. Army Facilities Engineering Support Agency Fort Belvoir, Virginia 22060		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Availability of this report is specified on reverse of front cover.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

BEI	Dual Species	Lakeland Series	Silviculture
Biomass	Effluent	Lakeland Soil	Slash Pine
Choctawhatchee Sand Pine	Energy Plantation	Longleaf Pine	Wood
Cogeneration	Energy Subsidy	Renewable Energy	
Combined Cycle	Gasification	Sand Pine	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study examines the silvicultural practices, harvesting methodology and managerial techniques pertinent to the operation of Choctawhatchee sand pine (CSP) plantations on Eglin AFB to establish Eglin as a Biomass Energy Island (BEI). Previous studies have demonstrated: (1) the feasibility of using wood grown on selected Air Force installations as the fuel to supply the energy requirements of each; and (2) the specific adaptability of Eglin AFB as a Biomass Energy Island (BEI). As such, Eglin would satisfy all

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20. energy needs of the facility by using 540,000 green tons of wood chips harvested from 90,000 acres of onbase energy plantations to fuel a gasification/combined cycle conversion system.

This study concludes: the technology of biomass conversion is appropriate for Eglin; both gasification and direct combustion cogeneration should be used for comparison purposes initially in the light of changing requirements; and the management of wood fuel plantations at Eglin and the phased establishment of the base as a BEI is both economically and technically sound and desirable.

*Other installations having the potential to supply significant portions of their heating energy requirements with timber grown on the installation are Arnold Engineering Development Center, Tennessee; Barksdale AFB, Louisiana; Tyndall AFB, Florida; and Avon Park/MacDill AFB,Florida.

EXECUTIVE SUMMARY

Our nation's dependency on uncertain supplies of imported oil has placed the United States in a visibly vulnerable position at a time of global political and economic instability. National security considerations alone dictate the development of locally available renewable energy sources.

Previous studies have demonstrated: (1) the feasibility of using wood grown on selected Air Force installations as the fuel to supply the energy requirements of each; and (2) the specific adaptability of Eglin AFB to establishment as a Biomass Energy Island (BEI). As such, Eglin would satisfy all energy needs of the facility by using 540,000 green tons of wood chips harvested from 90,000 acres of onbase energy plantations to fuel a combination of energy conversion systems.

This study examines the silvicultural practices, harvesting methodology and managerial techniques pertinent to the operation of Choctawhatchee sand pine (CSP) plantations on the Eglin BEI.

This study concludes: the technology of biomass conversion is appropriate for Eglin; both gasification and direct combustion cogeneration should be used for comparison purposes initially in the light of changing requirements; and the management of wood fuel plantations at Eglin and the phased establishment of the base as a BEI is both economically and technically sound and desirable.

The study recommends:

- The forestry department at Eglin AFB begin regeneration of the proposed CSP plantations;
- A review of the technological adaptability of Eglin to the BEI concept be undertaken to identify and quantify changes in energy consumption levels at the base; to correlate relative consumptions with conversion system design possibilities; and to determine ways to incorporate maximum flexibility in the energy conversion system(s) selected to deal with those consumption requirements;
- An in-depth design of conversion systems be initiated, and be so comprehensive in its integration of technology, operational requirements and the Air Force's commitment to the BEI concept that it could constitute a guide for the development of construction contract specifications.

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PREFACE

This report was prepared by Ultrasystems, Inc., Eastern Operations, 10340 Democracy Lane, Fairfax, Virginia 22030, for the US Army Facilities Engineering Support Agency, Fort Belvoir, Virginia 22060. The project was sponsored by the Engineering and Services Laboratory, Headquarters Air Force Engineering and Services Center (AFESC), Tyndall Air Force Base, Florida 32403, under Contract No. USAF MIPR N-82-11, as part of the Air Force Facility Energy Research and Development Program under Program Element 64708F, Project 2054 (Aerospace Facilities Engineering Development), Task 5 (Aerospace Facility Power System).

This report documents work performed between April 1982 and October 1982. It integrates the results and findings of work performed from February 1980 to January 1981 and July 1981 to January 1982. The Army Project Officer was Mr. Steven A. Helms, US Army Facilities Engineering Support Agency. The Air Force Project Officer was 1st Lt Paul C. Vitucci, AFESC, RDCS.

The report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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SECTION I

INTRODUCTION

1. BACKGROUND

The perpetuation of the "energy crisis" over the last 9 years has fueled a volatile global situation affecting every aspect of life in the industrial nations. This situation has demonstrated to the world that the United States remains unacceptedly dependent upon uncertain supplies of imported oil. The nation is in a visibly vulnerable position at a time of global political and economic instability.

Energy security is important to the United States but it is mandatory for the armed services. For the military, an alternative to liquid fuel dependency is a locally available energy source such as renewable biomass. The Air Force was quick to realize the vulnerability of its installations to fossil fuel interruptions and in 1978 embarked on an in-house study to evaluate the feasibility of utilizing wood grown on Air Force installations as fuel to supply the heating energy requirements of those installations, thereby replacing the conventional fossil fuels currently being used. That study, Forestry Lands Allocated for Managing Energy (FLAME), identified six Air Force installations with the potential for satisfying significant portions of their energy requirements with nonmarketable timber grown on the installation. The six selected installations are Arnold Engineering and Development Center, Tennessee; Avon Park Range and McDill Air Force Base, Florida, as a combined effort ; Tyndall Air Force Base, Florida; Barksdale Air Force Base, Louisiana; Eglin Air Force Base, Florida; and, the US Air Force Academy, Colorado.

Two followup studies to the FLAME study were subsequently conducted. The first study addressed the technical issues of interfacing biomass conversion systems with in-place energy systems and found that Eglin Air Force Base, of the six bases identified, had the highest technical and dollar payoff potential. That study proposed four sequentially greater biomass energy systems for Eglin Air Force Base. The second followup study to the FLAME study focused on Eglin Air Force Base as a model Biomass Energy Island (BEI) and addressed the issue of utilizing the installation's resources under a BEI concept. Based on the maximum wood fuel requirement of 540,000 green tons per year, that second study identified by use the 464,000+ acres of Eglin AFB; identified 90,000 net producing acres for inclusion in biomass energy plantations which would not interfere with the base's mission; developed five energy plantation options with associated yields; and recommended the superior option and the Choctawhatchee sand pine (CSP) as the species to cultivate.

The Biomass Energy Island concept, simply stated, is the ability of an installation to meet its facility-wide energy requirements for an indefinite period through the use of its own biomass resources without external energy supply. This study, which is an extension of the FLAME study and the two follow-on efforts, is the next step leading to the development and

implementation of this BEI concept which will provide secure energy sources to the Air Force.

2. OBJECTIVE

The objective of this effort is to develop and recommend a cost-effective, practicable means by which Air Force forested lands can be managed to supply appropriate wood fuel in the quantities required to support basewide biomass energy systems. The results of this investigation will provide a final comprehensive technical-economic scenario for implementing the BEI concept at Eglin AFB, in addition to supplying data which can be applied within the Air Force Facility Energy and Resource Conservation Program in a larger-scale effort to support air base biomass energy self-sufficiency.

3. SCOPE

This study focuses on Eglin AFB, Florida, as a model Biomass Energy Island. The study addresses these separate but related considerations in developing a basewide BEI system:

a. Selection of biomass conversion systems;

b. Identification of optimal timber management methods and silvicultural practices;

c. Determination of desirable methods and machinery for harvesting and transporting wood fuel;

d. Assessment of the effect which the establishment of Eglin as a BEI would have on management there;

e. Estimation of BEI support costs and manpower requirements;

f. Integration of the findings of preliminary studies pertinent to Eglin AFB as a BEI; and

g. Identification of subject areas needing further investigation.

4. SUMMARY

This study is the fourth in a series sponsored by the Engineering and Services Laboratory, Headquarters Air Force Engineering and Services Center, to explore the feasibility of developing a practical method by which the forested land on an airbase can be so managed as to provide the wood fuel to support a basewide biomass energy system. If found feasible, such a secure, renewable, local energy source could make an installation energy self-sufficient in the context of a Biomass Energy Island.

The study has explored the use of both a gasification/combined cycle biomass conversion system and a direct combustion cogeneration system initially in order to compare the efficiency of each relative to anticipated energy consumption requirements at Eglin AFB.

The study has examined the wood fuel needs of a BEI at Eglin, and has centered on the management of Choctawhatchee sand pine plantations. This has been found feasible, with minimal site preparation, and with planting and regeneration using seedlings, direct row seeding and broadcast seeding.

Implementation of the silvicultural practices reviewed, preferably on a contract basis, would substantially affect all forestry operations at Eglin, the study has determined. Concurrently, the study concluded that the base engineering system would handle, in stride, the implementation of a solid vis-a-vis an oil and gas fuel system.

From an economic standpoint, the BEI concept for Eglin AFB has emerged from this study as sound. The cost of energy conversion equipment, considering the saving generated by the fuel price differential, would carry with it an acceptable payback period. This is especially true in light of the benefit accrued; a secure, clean, renewable energy source. Further, any increased costs to the forestry system as an outgrowth of BEI implementation would in fact constitute fuel costs and should be accounted for as such.

The energy conversion system plans which have been proposed are presently not adequately in tune with updated energy consumption data and new management plans at Eglin. Two years have elapsed since the system was originally designed and its size visualized in terms of needs. In the interim, management organization and procedures have changed. This study has concluded that a detailed review of the technological aspects of Eglin's establishment as a BEI should be conducted promptly. This review, the current study found, should encompass changes in Eglin's energy consumption levels and the basis for incorporating optimal flexibility in whatever biomass energy conversion systems are selected.

SECTION II

BIOMASS CONVERSION SYSTEM

1. INTRODUCTION

The Technical Report, titled "Advanced Bio-energy Systems for Air Force Installations," the first of the Eglin AFB BEI studies, described and recommended energy-from-biomass conversion technologies to meet the BEI goals. The study proposed four sequentially greater biomass energy systems for Eglin Air Force Base. The initial systems, using two different technologies, were selected to allow for the demonstration and comparison of separate methods of biomass conversion to energy in full, on-line operation. *Demonstration Module: Option 1* is a gasification, combined cycle system producing 5,000 lbs/hr steam at 150 psig (saturated) and 4 MwH/hr electricity from a fuel wood feedstock of 170 green tons per day. *Demonstration Module: Option 2* is a direct combustion, cogeneration system producing 105,000 lbs/hr steam at 150 psig (470°F) and 3 MwH/hr electricity from a fuel wood feedstock of 480 green tons per day. The two initial systems can be implemented sequentially or together.

The third system, a combination of the two initial systems, was sized to satisfy the thermal requirements of the Eglin Air Force Base Main Base complex. The parameters are additive and amount to 110,000 lbs/hr steam at 150 psig and 7 MwH/hr electricity from 650 green tons of wood chips per day. The side-by-side placement of the two technologies, a gasification, combined cycle system and a direct combustion, cogeneration system, permits the demonstration and direct comparison of separate methods of biomass conversion in full on-line operation.

The fourth energy system, sized to satisfy the BEI concept (i.e., supply the energy for the entire base), is a centralized biomass gasification, combined cycle system which is an add-on to the Main Base system. The add-on will produce 25,000 lbs/hr steam at 150 psig and 20 MwH/hr electricity. The combined output will be 135,000 lbs/hr steam at 150 psig and 27 MwH/hr electricity produced from 1,480 green tons of wood chips per day.

The generated energies and the biomass demands of the four systems proposed are summarized in Table 1.

2. CHANGED CONDITIONS

The sizing of the conversion systems relative to total output of steam and electricity was based upon information made available at the time the initial study was conducted -- June-December 1980. Since that time, Eglin Air Force Base's Engineering Department has undergone several changes in staff and management. Accordingly, conferences with the new members of the department have revealed new data which will affect the already proposed energy conversion system plan.

TABLE 1. ENERGY BIOMASS DEMAND SUMMARY

SYSTEM	GTPD*	GTPY* (1000)	ENERGY OUTPUT
DEMONSTRATION MODULE OPTION #1	170	62	4 MWHR/HR 5,000 LB/HR 150 PSIG (SAT) STEAM
DEMONSTRATION MODULE OPTION #2	480	175	3 MWHR/HR 105,000 LB/HR 150 PSIG, 470°F STEAM
MAIN BASE	650	237	7 MWHR/HR 110,000 LB/HR 150 PSIG STEAM
ENTIRE BASE	1,480	540	27 MWHR/HR 135,000 LB/HR 150 PSIG STEAM

*GTPD/GTPY = GREEN (50% MC) TONS PER DAY/PER YEAR

a. High pressure (100+ psig) steam is no longer planned for wide application because all steam headers and distribution systems would have to be replaced and/or rebuilt, and all heating and cooling equipment would have to be retrofitted/replaced.

b. Central heating and cooling systems are no longer of primary focus, although they have not been ruled out as matters of concern to Eglin AFB staff.

c. A substantially modified listing of steam generating boilers and their ratings has been provided.

d. Extensive application of absorption cooling would have to be installed if steam were to be consumed in any quantity, consistently, in the summer.

e. Hurlburt Field has been removed from Eglin AFB energy consumption considerations.

f. Monthly energy consumption data for Eglin AFB for the last 4 fiscal years and annual consumptions for the 4 years preceding that time have been provided.

3. ANALYSIS OF NEW DATA AND PERSPECTIVE

Eglin energy consumption data for FY 81 were broken down into the various users' proportions, with scaling up of distributions from the first report to

allow for the exclusion of Hurlburt Field (Table 2). No other modifications to that distribution were indicated by Eglin officials. The annual energy consumptions and costs, the calculated average unit energy costs, the monthly maximum and minimum consumptions for the 2 years of available data, and the calculated monthly average consumptions were tabulated in Table 3. Because monthly data provided the shortest consumption interval available, the maximum, average, and minimum monthly figures were converted to common energy values for comparison, namely, Btu/hr. Standard military conversion factors were applied: 1 kWh = 11,600 Btu, and 1 SCF natural gas = 1030 Btu (Table 3).

Eglin's electricity and natural gas consumption data for FY 81 and FY 80, the two most recent fiscal years' data available, were tabulated, together with their calculated Btu/hr equivalents. To determine a seasonal variation/trend in the consumption of those energies, the amount of electricity consumption as a percentage of the total monthly energy consumption by the base for each month was determined and tabulated in Table 4. Electricity consumption was found to be relatively consistent over the 2-year span. In 10 of the 12 months, variance in consumption compared with the same months of the previous year was 3 percent or less. Electricity constituted at least 60 percent of all energy consumed for all months, and it was greater than 70 percent for all but three pairs of months.

Preliminary calculations indicate that, since the electricity consumption has increased by about 8 percent (27 MWh/hr to 29 MWh/hr) and the natural gas (thermal energy) consumption has decreased some 5 percent (730 to 694 x 10^8 Btu/yr), no change in the biomass feed requirement would be required relative to the previous report's data (Table 1).

Consumption of electricity and thermal-source energies has not changed considerably since the first report. However, Eglin AFB officials now feel that high pressure steam requirements are not as substantial as had been previously stated. If central heating and cooling systems are to be considered within the BEI context, it will be necessary to install a substantial amount of absorption cooling which would provide a summer steam load. Close examination will have to be made of the balance of mechanical (electrical) and absorption chillers so that the production of steam and electricity can be optimized. It is also important that the absorption chiller load be centrally located to minimize the steam distribution distances.

First impressions of consumption data and the revised energy consumption preferences favor gasification/combined cycle over direct combustion/cogeneration. The efficiency of direct combustion cogeneration systems is least when steam and electrical loads are markedly out of balance and when there are large variations in the size of each demand. Gasification/combined cycle systems, on the other hand, are indicated when a lesser proportion of steam is demanded relative to the electricity demand.

4. SUMMARY

The decision to pursue the Biomass Energy Island concept for Eglin AFB will carry with it the decision to modify energy use patterns and energy conversion equipment and, to the extent necessary, to develop a compatible

TABLE 2. FY 81 EGLIN ENERGY CONSUMPTIONS

User	Electricity[1] % of Total	Electricity[1] MWh/hr (Av.)	Electricity[1] Equivalent 10^6 Btu/hr (Av.)	Natural Gas[2] % of Total	Natural Gas[2] 10^3 SCF/hr (Av.)	Natural Gas[2] Equivalent 10^6 Btu/hr (Av.)	Total Equivalent 10^6 Btu/hr (Av.)
Hospital	7	2.0	23.2	4	3.2	3.3	26.5
Housing	28	8.1	94.0	34	26.9	27.7	121.7
Shopping	2	0.6	7.0	3	2.4	2.5	9.5
E. Ranges	1	0.3	3.5	1	0.8	0.8	4.3
W. Ranges	1	0.3	3.5	--	--	--	3.5
Field #6	1	0.3	3.5	1	0.8	0.8	4.3
Field #3	2	0.6	7.0	3	2.4	2.5	9.5
Ordnance Area	1	0.3	3.5	7	5.5	5.7	9.2
Main Base	50	14.5	168.0	45	35.6	36.7	204.7
33rd TFW	2	0.6	7.0	1	0.8	0.8	7.8
Federal Prison	1	0.3	3.5	--			3.5
Other (Misc.)	4	1.2	13.9	1	0.8	0.8	14.7
Totals	100	29.1	337.6	100	79.2	81.6	419.2

Total Base Consumption: 255,303 MWh/yr (Electricity); 694×10^6 SCF/yr (Natural Gas)

(1) 1 kWh = 11,600 Btu

(2) 1 SCF = 1,030 Btu

TABLE 3. EGLIN ENERGY CONSUMPTIONS FOR FY 74 to FY 81

	ELECTRICITY					NATURAL GAS				
FY	MWh/yr	Cost ($)	Av. Cost ¢/kWh	MWh/month Max./Av./Min.	Equivalent 10^6 Btu/hr Max./Av./Min.	10^6 SCF/yr.	Cost ($)	Av. Cost $/$10^3$ CF	10^6 SCF/month Max./Av./Min.	Equivalent 10^6 Btu/hr Max./Av./Min.
'74	226,214	3,082,562	1.36	na/18,851/na	na/300/na	578.035	488,430	0.84	na/48/na	na/68/na
'75	218,687	4,316,905	1.97	na/18,224/na	na/290/na	651.202	704,086	1.08	na/54/na	na/77/na
'76	231,019	5,285,152	2.29	na/19,252/na	na/306/na	679.111	786,168	1.16	na/57/na	na/80/na
'77	245,388	6,448,598	2.63	na/20,449/na	na/325/na	739.925	1,157,793	1.56	na/62/na	na/87/na
'78	242,800	7,843,802	3.23	Aug. Av. Dec. 27,800/20,233/15,834	Aug.Av.Dec. 433/322/247	783.678	1,567,652	2.00	Jan. Av. Jul. 143.628/65.306/26.670	Jan.Av.Jul. 198/92/37
'79	242,373	8,081,938	3.33	Jul. Av. Nov. 28,386/20,198/15,672	Jul.Av.Nov. 443/321/252	675.956	1,640,688	2.43	Jan. Av. Jul. 142.027/56.330/27.790	Jan.Av.Jul. 197/79/38
'80	244,208	8,822,753	3.61	Sept. Av. Dec. 29,136/20,351/16,266	Sep.Av.Dec. 469/323/254	685.529	2,122,939	3.10	Feb. Av. May 97.833/57.127/26.859	Jan.Av.Jul. 150/81/37
'81	255,303	11,184,182	4.38	Jul. Av. Dec. 35,789/21,275/15,889	Jul.Av.Dec. 558/338/247	694.040	2,465,081	3.55	Jan. Av. Jul. 122.106/57.837/27.848	Jan.Av.Jul. 169/82/39

Note: "na" is "information not available."

TABLE 4. EGLIN TOTAL ENERGY CONSUMPTIONS: VARIATION WITH SEASON.

	Electricity[1]		Natural Gas[2]		Total	
Yr/Month	MWH/Month	10^6 Btu/hr	10^3 SCF/Month	10^6 Btu/hr	10^6 Btu/hr	Elec. as % Total
'79/Oct.	19,917	311	89,332	124	435	71
Nov.	16,111	260	65,832	94	354	73
Dec.	16,266	254	98,939	137	391	65
'80/Jan.	16,472	257	89,332	124	381	67
Feb.	16,033	277	97,833	150	427	65
Mar.	16,664	260	67,237	93	353	74
Apr.	16,258	262	38,226	55	317	83
May	19,425	303	26,859	37	340	89
Jun.	24,670	398	28,572	41	439	91
Jul.	27,328	426	28,900	40	466	91
Aug.	25,928	404	28,032	39	443	91
Sep.	29,136	469	26,435	38	507	93
Oct.	17,669	275	36,417	50	325	85
Nov.	17,159	276	72,444	104	380	73
Dec.	15,889	248	99,457	138	386	64
'81 Jan.	16,514	258	122,106	169	427	60
Feb.	15,393	266	91,676	141	407	65
Mar.	18,317	286	77,485	107	393	73
Apr.	18,392	304	40,121	57	361	84
May	19,877	310	37,218	52	362	86
Jun.	28,715	463	29,520	42	505	92
Jul.	35,789	558	27,848	39	597	93
Aug.	26,968	420	29,911	41	461	91
Sep.	24,081	388	29,837	43	431	90
		(Av. 338)		(Av. 82)	(Av. 420)	(Av. 80)

(1) 1 kWh = 11,600 Btu

(2) 1 SCF = 1,030 Btu

energy system. Integration of thermal and electrical requirements, to include modification of existing systems, must be considered.

In view of changes in consumption data, and the necessity to review the approach to be adopted for a central heating/cooling system, it will be necessary to conduct a detailed review of the technological aspects of Eglin's establishment as a BEI. Feasible changes in Eglin's energy consumption levels and in their relative consumptions must be considered in any system design. Thus, not only must a more precise formulation of the technology and economics of the system(s) to be employed at Eglin be determined, but optimal flexibility must be incorporated into the facility proposed. The next step in the energy conversion systems design is an in-depth comprehensive conceptual design that integrates the technology, the basic operational requirements, and the Air Force's commitment to the BEI concept. Only then can answers be given to questions of systems requirements.

SECTION III

SILVICULTURAL PRACTICES

1. BACKGROUND

A tree, through photosynthesis, uses sunlight to convert elements in the soil and air to burnable carbon compounds. In effect, the tree captures solar energy and makes it usable in the form of wood. To maximize biomass production the effective photosynthetic area must be maximized during the life of the forested stand. This is accomplished by promptly re-establishing the stand after harvest and by spacing the seedlings so close together the canopy closes as quickly as possible. Under these circumstances, the maximum amount of available sunlight is captured and converted to wood, rather than falling on soil, or producing unusable weeds or grasses.

Silvicultural practices are the techniques used to manage a stand of trees from its birth (regeneration) through its harvest and succeeding regeneration. The practices appropriate in a given situation are determined by the characteristics of the species being managed, the climatic and edaphic conditions of the sites involved, and the goals of management, all conditioned by operational constraints. This section identifies and evaluates the alternative silvicultural practices and recommends a combination of options which can be utilized to manage biomass energy plantations effectively on the Lakeland series soil sandhills of Eglin AFB.

The silvicultural practices used in this country are those which were developed for the production of conventional forest products. Up until 1980 pulpwood and small sawlogs were the primary products envisioned by those involved with sandhill reforestation research. Energy biomass production was not an objective of this research. Currently, there exists no authoritative management regime, the goal of which is the production of energy biomass. The results of sandhill reforestation research,such as site preparation, planting, procedures for storage and seedling handling, and direct seeding, have application to both the conventional product plantation and the biomass plantation. This is not true of the spacing, thinning, and plantation management studies for sand pine that were established before 1980. Some early studies of seedling survival, however, and observation of the stands in which close spacing was used in these studies, justify reasonable estimates of spacing and rotation for biomass production.

In choosing between management alternatives the following three criteria were used as a guide and are listed in the order of their relative importance.

1. The practice should allow the maximum reliability in achieving energy self-sufficiency and biomass production.

2. The practice should be as cost effective and energy efficient as is practicable.

3. The practice should provide the maximum opportunity for the generation of information and its transfer to other installations.

2. SPECIES CONSIDERATION

Numerous species exist which are being grown and managed for biomass, either experimentally or in a production mode. It is imperative, however, to match the species selected with the specific site conditions, especially for a production project as extensive as is being considered at Eglin AFB. Of the three species discussed below, therefore, only the first two are acceptable for reforestation on the sandhills of Northwest Florida.

The Choctawhatchee variety of sand pine (CSP) (Pinus clausa var. immuginata Ward) is the best adapted of the 38 species of pines, 4 other conifers, and 5 hardwoods which have been included in trial plantings established on sandhill land during the past 50 years in northwest Florida. This variety of sand pine is now being planted on an operational scale on a range of sandhill sites in north Florida. It is the species recommended for use in the Eglin BEI.

Longleaf pine (P. palustris Mill.) is the only other species that can be recommended for sandhill reforestation. It is important to note, however, that Choctawhatchee sand pine will produce twice the volume of wood in 25 years as will longleaf pine when grown on a Florida sandhill site of similar quality and in stands of comparable density (Reference 1).

The third pine suited to sandhill reforestation, a native of sandhills land in central and eastern Florida, is Ocala sand pine (OSP) (P. clausa var. clausa). This variety of sand pine dominates much of the Ocala National Forest in central Florida and also grows well on similar sites along the Atlantic coast of Florida. It has been included in test plantings and also planted on an operational scale in northwest Florida, but with limited success. Transplanting survival of Ocala is generally much lower than for Choctawhatchee seedlings; it is more susceptible to defoliators such as the sand pine sawfly (Reference 2); its wood is less dense than that of Choctawhatchee; and it has proven to be very susceptible to damage by several root-rotting fungi which have caused serious mortality in plantations starting at a very early age (less than 10 years).

3. SILVICULTURAL SYSTEM AND METHOD

a. The "Evenage" System

An evenage system, in which all trees in a stand are the same age, with stand density and rotation designed to maximize wood production, is best suited to the species proposed, the management goals and the harvesting techniques anticipated at Eglin AFB.

b. Regeneration of CSP

Regeneration of evenage stands can be accomplished by either natural or artificial methods. Coppicing and pollarding are the two natural methods

traditionally used in other countries for the production of fuel wood. Neither method can be used with CSP because the cut tree does not sprout. Natural seeding is the only other natural regeneration method. This is not feasible either, because CSP grown in a close spacing and short rotation situation, as will be the case at Eglin, is not a reliable seedbearer. Therefore, artificial regeneration, following clear-cutting, is the only silvicultural method usable for the Eglin BEI.

4. MANAGEMENT PRACTICES

a. Site Preparation

On sandhill reforestation sites such as Eglin AFB, scrub oak and wiregrass compete with pine seedlings for nutrients and water. Site preparation readies the ground to receive seed or seedlings by exposing mineral soil, and it reduces competition to the newly established seedlings in the form of the undesired vegetation. No attempt is made to alter the physical lay of the land. Heavy equipment is used to crush and chop the above-ground growth and disrupt the root system in the top layer of soil. This is called "chopping." Standard practice in conventional reforestation is to single chop sites with sparse growth. In areas with denser growth, the first chop is followed in 6 to 18 weeks with a second.

There tends to be a direct relationship between survival and growth of sand pine and the thoroughness with which the site has been prepared. A comparison of the survival and growth of CSP sand pine on unprepared and chopped sites 10 years after planting at Eglin AFB is given in Table 5.

TABLE 5. SURVIVAL/GROWTH OF CHOCTAWHATCHEE SAND PINE ON UNPREPARED AND CHOPPED SITES 10 YEARS AFTER PLANTING (REFERENCE 3)

	Unprepared	Double Chopped
Survival (%) 1/	84	95.6
Avg. height (ft)	17.5	25.3
Avg. dia. (in)	1.9	3.5
Volume (ft^3/ac)	163 2/	712

1/ Seedlings planted at 6-foot intervals in rows 10 feet apart.

2/ Volumes are for the total stem.

The data in Table 5 appear to make a good case for site preparation. However, it must be remembered that these results are measured in terms of pine volume produced per acre, rather than on total volume pine plus hardwood (scrub oak) produced per acre. In biomass production hardwood control is unnecessary, since both pine and hardwood can be harvested and burned for fuel equally well. The concern with boiler fuel wood is not type or quality but rather quantity. CSP can survive and prevail where planted without any site preparation on scrub oak sites (Figure 1).

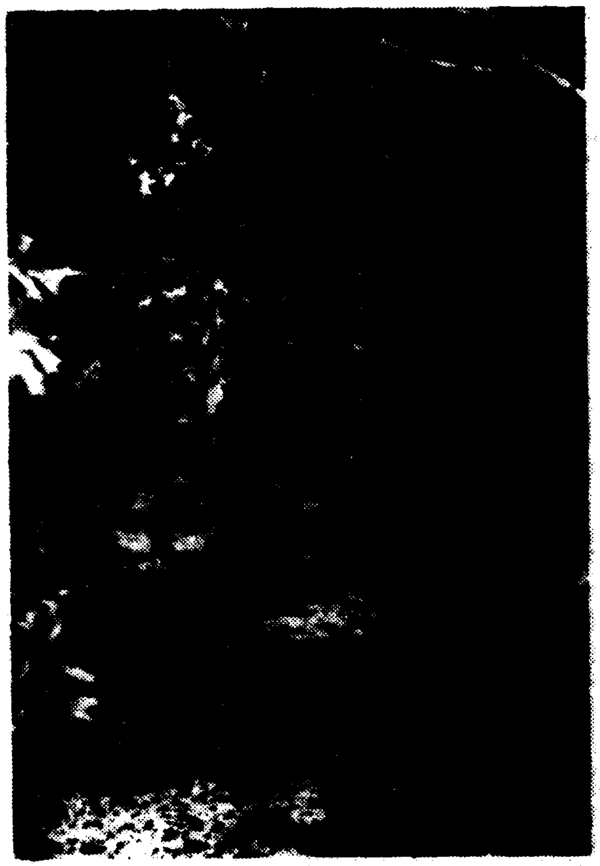

Figure 1. Sand Pine Planted Without Site Preparation

There are then three practical methods open for the preparation of sites for sand pine: single chopping at a cost of $27 per acre; double chopping at a cost of $52 per acre (current Eglin AFB contract rates); or no site preparation. "No site preparation" is slightly misleading in that the site would not be conventionally prepared by chopping, but would have the scrub oak growth harvested by clear-cutting and chipping. This action would clear and clean the area for regeneration with sand pine (Figure 2).

Figure 2. Site Condition After Harvesting Operation

The activity schedule (Section VI.4) projects chip harvesting for base needs to begin in the 5th year of the project. Prior to that time, removal can be accomplished under a "total removal" sale contract in which timber sale operators would remove the "unmerchantable" oak component of stands, along with merchantable sawlogs and pulpwood. Local fuel wood chippers have expressed a solid interest in such an arrangement and indicate that removal could be accomplished at no cost, or possibly with some profit, to the government. Consequently, we foresee the need for site preparation only during the first 2 years of the project while areas cut under existing contracts are being regenerated. During this period, we recommend the use of the conventional single and double chop.

b. Rotation and Stand Density

Two elements of forest management, rotation and stand density, are of key importance in biomass production. Rotation is the length of time between the establishment of successive stands. It consists of the period of time from regeneration to harvest (called the "felling age") plus the period of time following harvest until the stand is again regenerated, or stocked with trees (called the "regeneration period"). Rotation influences the total volume produced and the density (specific gravity) of the material produced; both are important factors in total energy production. Rotation also directly affects stem size and the ratio of stem volume to total branch, twig, and foliage volume. At the present state of the harvesting art, these two characteristics, stem size and stem/branchwood ratio, affect the efficiency of the harvesting operation and, hence, cost. Rotation is also a limiter of entry interval, the number of years between successive entries into a compartment.

(The latter is a major determinant of the quality of both wildlife habitat and visual resource.) Finally, rotation length determines the total area which must be regenerated each year. The longer the rotation, the fewer acres need be harvested and regenerated annually.

Stand density, or stocking, is expressed as the number of trees per acre. It affects the volume produced, the stemwood/branchwood ratio, the tree size and, very importantly, the cost per acre of regenerating the stand. The nature and direction of the impacts of these two key variables, rotation and stocking, on biomass production is shown in Table 6.

TABLE 6. IMPACTS OF ROTATION AND STOCKING

Method \ Attributes	CUT PER ACRE	TREE SIZE (DBH)	SPECIFIC GRAVITY	BOLE/BRANCH RATIO	ACRES TO REGENERATE	REGENERATION COST PER ACRE
LENGTHENED ROTATION	⬆	⬆	⬆	⬆	⬇	NA
INCREASED STOCKING	⬆	⇩	NA	⬆	NA	⇧

Notes:
1. The direction of the arrow indicates the direction of the impact. A solid arrow indicates favorable impacts (increased energy and cost efficiency); an open arrow indicates adverse impacts.
2. DBH is a tree's diameter at breast height.

The largest average annual volume yield from a stand is achieved by cutting the stand at the "culmination of mean annual increment" -- the age at which average per acre production peaks. For CSP, this lies between the ages of 10 to 15 years, depending on stand density, site, genetic quality of seed or seedlings, fertilization regime, and other factors. It can be seen from Table 6 that, within the limits set by the culmination of mean annual increment, a longer rotation would produce the more favorable results. The recommended rotation, therefore, is 15 years (a 14 1/2-year felling age plus a 1/2-year regeneration period).

Actual .utting age for individual stands may vary slightly to allow flexibility in management. Should new research indicate the desirability of a shorter rotation, the adjustment can be made easily.

The net effort of changes in stand density is not readily apparent, with an evident conflict between yield and cost. (One 12 1/2-year old experimental CSP plantation with a stocking of 5,008 trees per acre has produced at an annual rate of almost 9 green tons [total tree yield] per acre. At the same age, a planting with 2,675 stems per acre produced about 5.7 green tons per acre per year. (Reference 4) In actual practice, stand density will vary considerably, depending on seeding or planting rate and survival rate. Taking all factors into account, including those discussed in the following subsection, the objective at Eglin will be to obtain a stocking of 2,000 to 5,000 trees per acre.

c. Planting/Seeding

In considering CSP generation at Eglin AFB, three modes must be examined: planting seedlings (Figure 3), row seeding (planting the seeds in clearly defined rows, Figure 4), or broadcasting seeding (seeds being scattered on the surface of the ground). Each Method has advantages and disadvantages in its application at Eglin under a BEI concept. Each must be evaluated in conjunction with many other variables such as seedling or seed availability, survivability, cost per acre, operational track record, research findings, the genetic background of the seed or seedling, and the desired stocking rate (stand density).

Figure 3. Seedling Planter

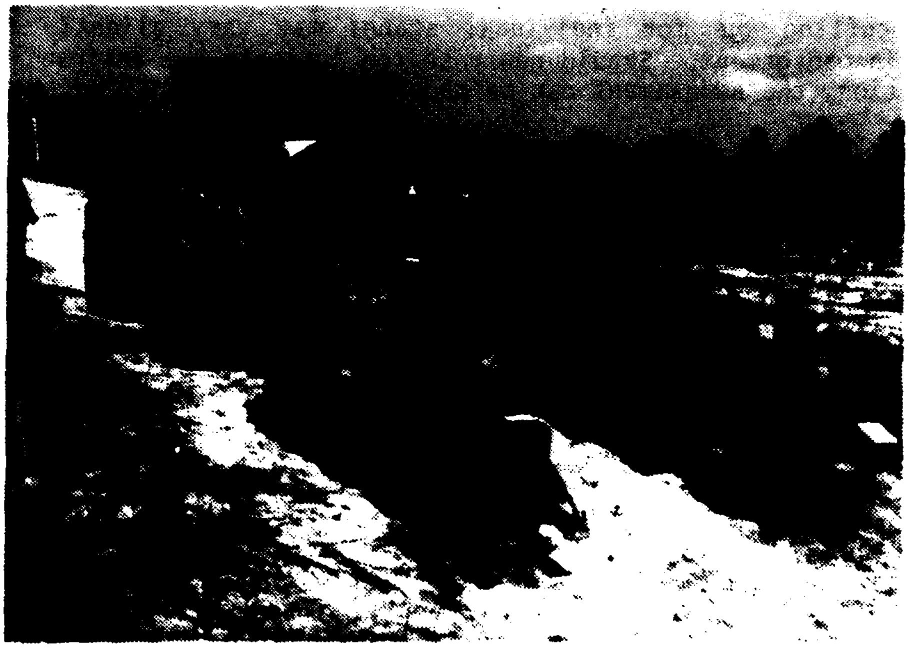

Figure 4. Machine Seeder Used in Direct Row Seeding

Either planting or seeding can be used to reforest the sandhills of Eglin. All the commercial artificial stands of CSP in northwest Florida have been planted, and planting is the only mode now being used by industrial forest managers. Planting seedlings, however, is both expensive (especially for high density plantations) and energy intensive. Planting costs for CSP energy plantations are estimated at about $100 per acre; this contrasts with an estimated cost of $18 per acre for broadcast seeding. U.S. Forest Service experience with OSP on the Ocala National Forest in central Florida and studies of CSP seeding in the north Florida sandhills (References 5 and 6) both suggest that good growth and survival can be obtained with seeding of CSP in northwest Florida.

Compelling arguments for the serious consideration of seeding are seeding's low comparative costs and high-energy efficiency. An additional consideration is that seedlings must be ordered a year ahead of use and used relatively soon after delivery. Delivery, handling, and storage of seedlings must be coordinated with the planting operation, and experience shows this may become a major problem. Seed, on the other hand, can be collected and used in the same month or stored for years.

One other consideration, of special significance on public land, and especially Eglin AFB, is the apparently natural condition produced by seeding as contrasted to the artificial appearance of planted rows of trees. Part of the "alternate" area within Management Compartments 5 and 10, as shown in Figure 7 of the Resource Alternative Technical Report, lies within the environmental zone. In this area, testing requirements mandate the

preservation of natural appearances. Should the Air Force decide to permit energy production within this area, regeneration will be by seeding rather than planting.

A comparison of the relative advantages of seeding and planting is shown in Table 7. No clear-cut advantage favors either planting or seeding. Considering the size of the effort at Eglin AFB, the time involved, the lower cost, higher energy efficiency, higher density of the stands, and the more natural appearance, direct broadcast seeding is viewed as the preferred method. However, because of the research and developmental nature of this project and because research and experience should provide a more complete body of knowledge in this area, a combination of planting and seeding is proposed.

TABLE 7. COMPARISON OF PLANTING VERSUS SEEDING CSP

METHOD / ATTRIBUTES	PROVEN RELIABILITY (CSP)	PROBABLE RELIABILITY (RESEARCH & OSP BASED)	RELATIVE COST PER ACRE	SEED USE EFFICIENCY	USE FLEXIBILITY	ENERGY EFFICIENCY	NATURAL APPEARANCE
SEEDING	—	Mod	Low	Mod	High	High	High
PLANTING	High	High	High	High	Low	Mod	—

Note: The shaded block indicates a relative advantage in that area

The supply of stock needed will be substantial, whether seed or seedlings are used for stand regeneration. With the rotation and close spacing proposed for efficient biomass production, approximately 15 million seedlings per year will be required to reforest some 6,000 acres annually. This is over three times the present total yearly sand pine seedling production of the Florida State Division of Forestry. Further, that organization's production is fully committed to existing demands. The Division can expand its production, however, by some 10 million seedlings per year, depending on the availability of seed and money (Reference 7).

Establishment of a nursery at Eglin AFB has been suggested as an alternative. Such a facility would require a large capital outlay, however, and could present serious problems in site selection, construction and operation. Additionally, nursery operation is highly energy intensive; it entails irrigation, fertilization, cultivation, application of fungicides and pesticides, plus the lifting, grading, transporting and storing of the seedlings.

Broadcast seeding, at a rate of .25 to .5 pounds per acre, will seed two to four acres with a pound of seed. Row seeding, using .15 to .2 pounds per acre, will reforest five or six acres with a pound of seed. Seeding of 6,000 acres would require 1,000-3,000 pounds of seed annually. Although seed production per bushel varies widely from year to year, one bushel of cones will produce an average of about .4 pounds of seed (Reference 7). This means 2,500-7,500 bushels of cones will be needed each year. Though Eglin AFB has the forest resource to provide this quantity of seed, the current cone collection system cannot do the job.

An adequate supply of CSP seed, therefore, is the limiting silvicultural factor in the CSP biomass program at the scale proposed. To implement the program, existing natural stands of CSP at Eglin should be managed primarily for seed production. There is now a small, 10-acre, seed orchard at Eglin. The growth of seedlings from this orchard seed may be 10 to 20 percent greater than seedlings produced from "woods run" seed. Consideration should be given to expanding this orchard incrementally so that eventually the whole CSP program could be based on improved plant material.

Considering all factors discussed above, these actions are proposed:

1. Increase seed orchard from 10 to 50 acres. Begin collection of superior seed and use all of the improved seed for the production of seedlings for regeneration planting.

2. Revise cone collection procedures as outlined in Management Impacts.

3. Within the ability of the State Division of Forestry, provide seedlings without reducing the supply of State-produced seedlings to industrial and individual users, plant up to 3000 acres annually (approximately 8 million seedlings at an assumed rate of 2,700 seedlings per acre). Planting will be in operational units with stocking ranging from 4 x 5 (2178 per acre) to 3 x 4 (3630 per acre) depending on research needs and available seedlings. This will require 320 pounds of seed or a minimum of 800 bushels of cones from Eglin.

4. a. Seed the balance of area to be regenerated (estimated to be a minimum of 3,000 acres annually), using both broadcast and row seeding techniques. Seeding rates will be from .15 to .5 pounds per acre, averaging .25 pounds per acre, depending on research needs and available seed. This will require an estimated 750 pounds of seed, or 1900 bushels of cones annually.

b. Eglin AFB is the sole source of CSP cones for the State reforestation program. To maintain its supply of seedlings for users other than Eglin AFB itself, the State will need 180 pounds of seed, or 450 bushels of cones, annually. Total cone production from Eglin AFB, therefore, must be about 3,150 bushels per year.

5. a. Defer decision on establishing a nursery facility at Eglin AFB until final planting needs are known.

b. Defer decision on construction of cone processing and storage facility at Eglin until final planting and seeding needs are known.

d. Fertilization, Irrigation and Nutrient Depletion

Fertilization and irrigation are practices which may increase total production in a biomass plantation on a sandhill site. Irrigation would not be an economical operation and cannot be given serious consideration. Sand pine will respond to applications of fertilizer, especially to nitrogen and phosphorus, the elements most affecting tree growth on sandhill sites. The application of nitrogen and phosphorus to conventionally spaced CSP plantations, however, has not produced a growth response sufficient to justify fertilization at the current price of these fertilizer materials (Reference 3). It is quite possible that in biomass plantations, because of the closer spacings, there will be a greater uptake of the fertilizers applied with greater growth responses the result. Test CSP biomass plantations were established in 1980 that included fertilization with nitrogen, phosphorus, and sewage sludge. The latter is a material well suited to sandhills fertilization when available in sufficient quantity and in an easily distributable form. The results of these test plantations should be studied closely and the findings integrated with the results achieved on Eglin AFB plantations to form a final definitive plan.

If fertilization is needed or desired there is one approach which may be economical. The accumulated fly ash and bottom ash from the wood combustion unit(s) have nutrient value and would be available in quantity; approximately 20 pounds of ash would be realized for each ton of wood consumed. However, this ash also has a commercial value as fertilizer, and,as such,can be sold to generate revenue. The economics of this situation, use versus sales, need further analysis. The application method, cost,and timing also need study if ash fertilization is to be used at Eglin AFB.

Related to the question of fertilization is the potential problem of nutrient depletion. Energy biomass harvesting, which will remove all organic material at short intervals, may result in loss of site productivity. At present there is insufficient information to evaluate the extent of this potential problem adequately. Research underway and planned should resolve these questions before Eglin AFB harvests the first biomass plantation. (See Section VIII, Areas for Further Investigation.)

e. Thinning and Burning

Thinning is a measure designed to maximize size and quality by concentrating growth in selected trees. This is accomplished by removing a predetermined percentage of the stand to give the remaining trees more room and nutrients. This practice is not deemed appropriate for the management of the BEI concept at Eglin AFB where maximum volume production is the goal.

Prescribed burning, which is used to control undesirable species or to reduce the risk of damage by wildfire, is also not deemed appropriate. Where pine is preferred to scrub oak because of the former's more rapid growth, there are no "undesirable" species when growing biomass for boiler fuel. Prescribed burning in developing pine stands is a high risk venture and loss probability under a prescribed burning program is higher than that expected from an occasional wildfire. (Any material deadened by a prescribed burn in a CSP plantation would be less than 1 inch DBH and not usable for chips.)

f. Existing Pine Plantations

Three types of pine plantations occur within the area to be considered for energy wood management; longleaf, slash and sand pine. Adequately stocked longleaf plantations will produce acceptable quantities of high quality wood and utilize the land to good advantage. They should not be harvested for energy biomass.

Some 13,000 acres of slash pine occur within the Eglin energy wood management area. They have proven to be a disappointment in terms of growth and survival. In many areas the scrub oak has regained a substantial foothold and forms a major portion of the stand. Slash pine plantations should be clear-cut and chipped for energy wood, and regenerated to CSP. As they generally support a higher volume (avg. 30 tons/ac) than scrub oak stands (10 tons/ac) they should be scheduled for cutting during the last half of the first 15-year period, when the volume will be needed to meet the Base's energy chip needs.

Sand pine plantations now total about 20,000 acres within the area to be managed for energy wood. Their production will be high (avg. 80 tons/ac) and should be reserved for harvest during the latter part of the first 15-year period.

g. Interim Use of Ocala Sand Pine

The interim use of Ocala sand pine (OSP), in the event that sufficient CSP seed or seedlings is not available for the biomass plantations, has been suggested. This does not appear to be a reliable alternative. A recent sand pine root disease survey (unpublished results) is summarized in Table 8 (Reference 3).

Root disease, primarily Clitocybe tabesceus (Fr.) Bres., is a serious problem in Ocala plantations in west Florida starting at a very early age. The damage (wind throw) is also much more serious for OSP than has been reported for CSP. Symptoms of the root disease (resin soaking of the bole

Table 8. Incidence of Root Disease by Percentage.

Age Class	CSP	OSP
0- 5	0.4	18.6
6-10	1.1	20.5
11-15	25.5	30.4

near the ground) can be found in CSP, but actual damage is far less than is true for OSP. Resin-soaked stumps can be found in the old growth CSP stands that have been harvested on the Eglin AFB. This resin soaking, a condition that probably took years to develop, may have been caused by root-rotting fungi, but the process apparently is much slower in CSP than in OSP; consequently, little actual mortality is found in CSP stands.

It is strongly recommended that due to its poor "track record," investment in OSP plantations not be undertaken for any purpose.

h. Additional Considerations

(1) Insect Infestation

CSP has few natural enemies. It is attacked by tip moth, but such attacks have not retarded its growth (References 3 and 8). The sand pine sawfly has been reported in west Florida, but it has proven to be primarily a problem of the more open, Ocala plantations. This sawfly apparently does not develop to serious population numbers in dense stands, the condition to be expected in biomass plantations. The CSP variety of sand pine appears to be more susceptible to bark beetles, primarily Ips, than other southern pines such as slash, longleaf and loblolly. This may be due to the fact that sand pine is thin barked and much less resinous than any of the above pines. Beetle attacks occur primarily when the trees are in stress conditions caused by drought, lightning damage or damage by fire. Beetle damage has not been noted in dense stands of small diameter CSP.

(2) Disease

CSP is susceptible to a gall rust (Cronartium quercum) which produces branch galls of little importance and does not produce stem galls. CSP is not susceptible to fusiform rust (Cronartium fusiforme).

(3) Animal Damage

No grazing by domestic stock takes place on Eglin AFB. The base supports a good population of Virginia white tail deer, and this is expected to increase under energy wood management. Sand pine seedlings are not a preferred browse species of white tail deer, and no deer damage has been reported to plantings of this species on the base.

SECTION IV

HARVESTING AND TRANSPORTATION

1. BACKGROUND

The harvesting and transportation of the wood fuel is a vital segment in a BEI concept due to its impact on the entire system.

The methods of harvesting are of primary importance in the management of energy biomass. As might be expected in a new technology, the harvesting of energy biomass is undergoing rapid and drastic change. The methods and machinery now being used can be expected to undergo considerable transformation in the next few years.

Biomass is harvested in a clear-cutting operation. In this single whole-tree-chipping operation, the entire above-ground portion of the tree is reduced to chips which are blown into a van and transported to a storage area in a wood-handling yard.

A well-run chipping operation leaves the ground almost clean and in excellent shape for establishing the new stand, Figure 5.

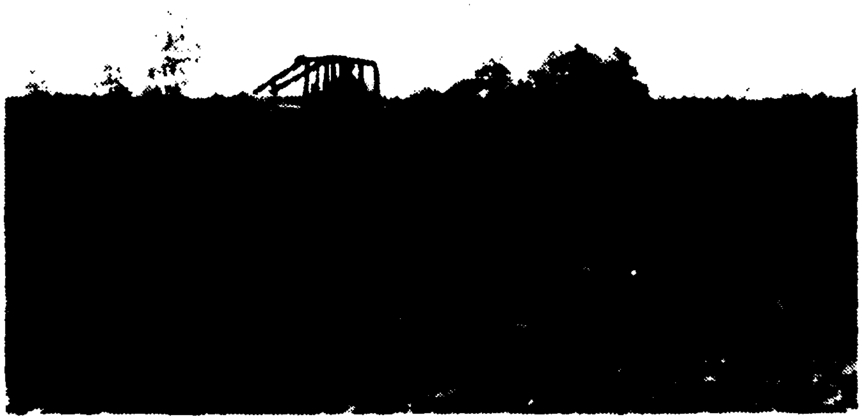

Figure 5. Site Condition After Whole-Tree Chipping Operation

2. SYSTEM CONFIGURATION

The typical system involves some combination of three machines, the exact makeup varying with cut per acre, size of trees, terrain, and other factors. The basic combination consists of a feller-buncher, a grapple-skidder, and a whole-tree chipper. The feller-buncher, Figure 6, severs the stem at groundline with a hydraulic shear and piles the cut trees. The grapple skidder or a variation thereof called a "forwarder," Figure 7, then drags the pile to the chipper, which is really the key unit in the combination. The chipper, Figure 8, reduces the whole tree to chips and blows them into a van.

Figure 6. Feller-Buncher

Chips are moved from the woods to the wood-handling yard by the vans which average 20 to 30 tons capacity. An operation producing 250 tons per day with a 10-mile haul, about average for the Eglin AFB operation, would require 10 round trips per day. In full operation, the Eglin AFB project would involve 7 to 9 chipping units. A yard tractor with blade and a maintenance and fuel truck complete the harvesting equipment team. The total chipping operation requires from 6 to 8 men, not including truck drivers, depending on the combination of equipment used.

A typical combination for a single chipping operation at Eglin AFB would be as follows:

Figure 7. Grappler-Skidder

Figure 8. Whole-Tree Chipper

1 chipper

3 feller-bunchers

2 skidders

vans and 1 or 2 trucks

1 maintenance pickup

This combination could be expected to produce the chips, under contract, at a cost of $11 to $14 per ton FOB yard. See Section VI for inclusive cost data.

a. Near-Term Advancements

Some seven such units are now being operated by contract loggers in north Florida, primarily on lands owned by the forest industry. It is believed that these units may be overdesigned for the small material which will be produced by biomass farming, and it is expected that more efficient machinery specifically designed for small whole-tree harvesting will be in use in the near future. Currently, there are numerous prototype chippers being developed around the country, many of which will be totally operational by the time the first wood chip is harvested for fuel at Eglin AFB. One such device, a prototype mobile combine chipper operating without the need for a feller-buncher and grappler-skidder, is now in operation in California.

An advancement in harvesting, called "transpirational drying," pioneered at Clemson University and being further tested at the University of Florida, may have significant application to the BEI concept at Eglin (Reference 9). The potential benefit stems from delaying the chipping operation. Normally, the chipping is done at the time the tree is felled. Tests indicate that if the felled tree is left on the ground for about 8 weeks before chipping, the wood dries, losing about 50 percent of its moisture. This increases the Btu value of the chips, lessens total wood fuel consumption, and saves hauling costs as a result of less weight.*

Current modifications in the chipper are resulting in changes in both size and configuration of the chips. These changes enhance chip manageability by reducing layering and bridging, and they facilitate air circulation in storage, thereby reducing moisture content and chip deterioration.

If tests such as these continue to show such results, the techniques demonstrated could offer potential for considerable saving at Eglin in view of the magnitude of the operation visualized there.

*NOTE: Same volume is necessary. Truck will be fully loaded as before—same number of trips necessary for the same volume--however, each load will have more net energy, weigh less and use less fuel for hauling.

SECTION V

BEI IMPLEMENTATION AND THE IMPACT OF MANAGEMENT

1. BACKGROUND

This section investigates the changes needed in the system of forest management at Eglin AFB to permit implementation of the energy plantation management recommended previously. Through discussion with base staff and analysis of organization and process flow, a number of steps have been identified which have been categorized as either "imperative" changes or "desirable" changes. "Imperatives" are essential to the success of the project. "Desirables" will increase work effectiveness and enhance the probability of success.

Changes are considered in the following order:

a. Selection of the implementation mode used to effect the management specified in Section III. Mode selection provides the planning framework within which other management modifications can be considered.

b. Technical changes needed to permit operation under the implementation mode selected in a. above, and to support the management specified in Section III. Technical changes include procedural or methodological changes which can be accomplished within existing policies, regulations, and organization.

c. Institutional changes needed to support the selected implementation mode, the technical changes needed, and the management program specified in Section III. Institutional changes are of two kinds: (1) changes in law, regulation or policy, and (2) changes in organization and responsibility, attitude, and perceptions. The latter changes involve human behavior of management change and may be the most difficult to bring about.

2. IMPLEMENTATION MODE

Three implementation options were considered:

a. Operations contracted with contractor-owned equipment (contract for service and equipment).

b. Operations contracted with government-owned equipment (contract for service only).

c. Government operation (force account).

A contract for service and equipment would be a totally contracted operation in which the contractor owns and operates all necessary equipment and provides all needed manpower, equipment, and supplies with certain necessary exceptions. The government plans the activities and prepares and administers the contract. Maximum scope for such a contract would be a total turnkey job in which a single contractor would handle the entire energy production job: biomass production, harvesting and transportation, plus power generation. At the other extreme, the process could be compartmentalized into a series of discrete operations: site preparation, seeding or planting, chip harvesting, chip delivery and power generation. Logically, contracting should be structured to conform to trade practices and capability of probable contractors. At the same time, it should allow maximum integration of operational components to make for centralization of authority and responsibility. Such an arrangement would increase both the ease of administration and the efficiency of the operation. The Northwest Florida, Southeast Alabama, Southwest Georgia region has a number of qualified contractors capable of handling either a turnkey reforestation or harvesting job. A lesser number of major consulting forestry firms have total forest management coordination capability. A single multioperation management contract covering the entire biomass production, harvesting, and transportation facet of the project would most nearly meet the objectives of reliability and cost effectiveness. This is the recommended implementation mode.

The two other options, contract for service only and force account, were also considered. The first has little to recommend it. Major contractors in the area have, or have the credit rating to acquire, all needed equipment. Ownership of equipment carries with it the responsibility for maintenance and replacement. Maintenance is difficult to divorce from operation, and owner-operation is much more likely to result in low equipment operation and replacement costs than is a situation involving dual responsibility. The use of government-owned equipment with contract operators is not recommended except in temporary and unusual circumstances, such as experimental use of newly developed and/or expensive equipment.

In theory, a well-run force account operation, by people who have a continuing interest in and understanding of the job, will produce a better quality job than a contract operation. However, experience in a wide variety of conditions has shown that a government force account operation is less cost effective and more burdensome administratively than a contract job. Demonstrated problems arguing strongly against the use of a government work force to implement this project would include: efficient utilization of employee downtime; hiring, firing and discipline; application of the Fair Labor Standards Act regulations regarding the 8-hour day and 40-hour week; and administration of procedures pertinent to callback time, environmental differential pay, high fringe costs and labor-management (union) relations. Finally, existing restrictions on employee ceilings, plus the current administration's posture on increased reliance on the private sector, preclude a move in this direction. The force account option was rejected.

3. TECHNICAL CHANGES

Five changes were identified as being needed in the current process of forest management at Eglin AFB. Two of these, a revision in the method of cone collection and a doubling of the acreage regenerated, are considered imperatives. The research efforts discussed in Section VIII will require changes in some management specifics. These can be accomplished by varying the annual program as needed.

a. Cone Collection

Sand pine produces a good cone crop every 6th year with poor to fair crops in intervening years. The seed stores well. Cone collection at Eglin AFB now is accomplished as follows: About 100 acres of large crowned natural (rather than planted) sand pine is located in the spring of the year and the trees are marked and sold in a commercial timber sale with the stipulation that they be cut during the period of September 15 through October 30. This is the period in which cones are mature but have not yet opened and dispersed their seed. In the fall of the year, the forestry staff issues a permit and a map of the cutting area to persons wishing to collect cones. These individuals collect the cones and sell them to the State Division of Forestry. This method is believed to result in a "creaming" of the most easily gathered cones and constitutes poor utilization of the resource.

As pointed out in Section III, the availability of seed may be the limiting factor in a major reforestation program. The present system, with its limited scope, problems of coordinating cutting and collection, and the lack of quality control in the collection process, will not yield the volume of seed needed for the BEI program. It is recommended that the system be completely revised to bring the entire process of cone collection, tree felling, cone gathering and cone distribution into a single contract with control and administration by the Eglin AFB Forestry staff. Only in this way can the production of an adequate cone supply, over 3,000 bushels annually, be assured.

There are 57,000 acres of natural sand pine stands on the base. To achieve a sustained annual yield of 3,000 bushels of cones, a large part of this acreage must be managed specifically for that production purpose. This cone management acreage will become an essential part of the energy wood production system. The preparation of a cone management plan which will identify these acres is recommended later. This is a necessary early step in the implementation of the BEI program at Eglin AFB.

b. Increase in Sales and Regeneration Program

With the initiation of an energy biomass program, Eglin AFB will have two forest management programs, both handled by the same staff, but each funded from a different source and each with a different goal. One of these will be the production of energy wood from acreage "dedicated" to this purpose, 90,000 acres plus whatever acreage is needed for cone production. The other will be the production of conventional forest products from available acres not needed for energy wood.

This study, while considering primarily energy wood production, must also address the problem of conventional product sales since the readying of energy wood areas for production will require the removal of large volumes of conventional forest products. At the same time the need for management of the resources on other base lands will continue. For planning purposes we have assumed that conventional forestry programs for "nondedicated" lands will proceed at a pace consistent with the reduced acreage available. The existing and proposed programs are shown in Table 9.

TABLE 9. SALES AND REGENERATION PROGRAM

		CONVENTIONAL		ENERGY WOOD		TOTAL	
		Acres	Volume	Acres	Volume	Acres	Volume
EXISTING	Clearcut	3000	3000 MBF	——		3000	3000 MBF
	Thin	3000	15,000 cds.	——		3000	15,000 cds
	Stump		7000 tons	——			7000 tons
	Regeneration						
	• Long Leaf	3000		——		3000	
	• Sand Pine	0		——		0	
	—— FIRST FIVE YEARS ONLY ——						
PROPOSED	Clearcut	1000	1000 MBF	6000	6000 MBF	7000	7000 MBF
	Thin	3000	15,000 cds.	——	——	3000	15,000 cds.
	Stump		1000 tons		10,000 tons		11,000 tons
	Regeneration						
	• Long Leaf	1000				1000	
	• Sand Pine	0		6000		6000	

The sand pine regeneration program must remain in effect until 90,000 acres are in energy plantation. The timber types on the area to be regenerated will change over the initial 15 years of the project. In general, scrub oak areas or sparse natural sand pine stands will be regenerated first, followed by offsite slash pine plantations and finally sand pine plantations. The volumes shown are for the first 5- year period, based on these assumptions: that sawtimber will be harvested for saw logs, rather than being chipped; that stumps will be cleared from energy wood areas; and that the normal thinning program will remain in effect. The volume of saw logs removed from energy wood areas will persist into the second 5- year period when the shift from scrub oak/longleaf stands to offsite slash plantations will substantially reduce the volume of sawtimber sold. With the information now available, the extent of this volume change cannot be predicted.

The major changes in acreages, goals and volumes will require the revision of the existing forest management plan (Eglin Air Force Base Comprehensive Natural Resources Plan, August, 1974 update), as recommended later. Volumes and acreages are tentative, pending preparation of this plan and of the core management plan previously discussed.

c. Seed/Seedling Management Agreement

At this time the cone/seed production arrangement between the Air Force and the Florida Division of Forestry is handled by informal, verbal agreement renewed each year. Under the system proposed in this plan the State will handle seed extraction and storage, and seedling production. As the volume of seed and seedlings drastically increases, a more formal agreement will be necessary if misunderstandings and slippages are to be avoided. It is desirable that the Air Force and the Division of Forestry jointly prepare an umbrella agreement with provision for annual program changes.

d. Area Control Management

Management of energy plantations will require area control, i.e., close accounting of acres cutover, regenerated and in various stages of development. The forestry staff has this capability in the present Air Force Management Information System.

The system now used for management involves two levels of control: the compartment and the stand. There are 10 compartments of approximately 40,000 acres each; each compartment contains about 200-300 stands. The staff examines selected timber stands in one compartment a year and prescribes the action needed for management. Each stand is treated separately and the record for each stand is maintained separately.

This system is not appropriate for the much more intensive management required for a biomass production system for several reasons: the compartments are not laid out or positioned to encompass the area which will be used for biomass production. A biomass system will require coordinated management within relatively small areas on a 5-year re-entry basis, rather than on a 10-year period. The heavy management activity volume, especially harvesting, generated by this project will require dispersal of activity centers in order to avoid conflict; the present method concentrates activity. Finally, the physical act of locating a specific stand on an area map containing perhaps 400 numbered stands, especially as these stands shift and change over time, will be a continuing problem.

To overcome these problems, the use of a typology of management units is recommended and shown in Table 10.

e. Compartment Prescriptions

Regardless of the adoption of the typology of management units recommended above, an early initial examination of all areas suitable for energy production, primarily Lakeland soils, should be conducted. This is needed to delineate planned stands and areas of potential resource conflict; to set priorities for cutting and regeneration; to determine volumes to cut commercially and volumes available to chip; and to identify road construction or reconstruction needs. The planning document produced by this activity will ensure that other resource needs are considered and built into the management of the land. Coordination of activities will be required, not only within each compartment, but also between compartments and with the overall base energy

TABLE 10. AREA MANAGEMENT

Management Unit	Approximate Area	Purpose
Block	50,000-200,000 acres	Administrative management unit. Differentiates between areas of different management goals or intensity.
Compartment	1,000-2,000 acres	Record management unit. The basic area for re-entry, examination and timber sale.
Stand	20-200+ acres	Timber management unit. A treatment unit in which all trees are of the same age and condition class. This is the specific area which will be harvested, regenerated, etc.

Block and compartment boundaries should remain unchanged except for changes in management goals. Stands may divide or combine over time as natural forces or intensified management change the condition of the timber within these stands.

conversion phase-in schedule. Careful preparation of compartment prescriptions is probably the single most important action that can be taken to assure quality management.

f. Other Considerations

The energy program will require an increase in road maintenance and construction. The extent of the increase is problematic, but will not be excessive or difficult for base engineering to handle.

The level of fire protection needed is determined by two factors: risk and hazard.

Risk is the probability of a fire starting. At this time the major risk is from the military operation. An increase in harvesting and regeneration means more equipment and men in the woods, with a consequent increase in risk.

Hazard is a measure of the probability of a fire spreading and reflects the difficulty of controlling a wildfire. Because chipping operations will greatly decrease the amount of logging debris left in the woods, fire hazard will be significantly reduced. The dense stands of even-aged pine which this

project will require are susceptible to crown fire. Normally, this would increase the fire hazard. However, the planned dispersal and position of these stands and the interspersion of low-hazard scrub oak stands (required for wildlife, esthetics and endangered species management) will actually reduce the overall hazard.

On the whole, no increase in the fire protection needs is anticipated as a result of the biomass energy production program.

4. INSTITUTIONAL CHANGES

Five institutional areas have been identified in which changes are indicated if the energy biomass concept is to be successfully implemented at Eglin AFB. Three of these are considered imperative -- they must be made if the project is to succeed. These are:

- o Methods by which base forestry operations are financed.
- o Staffing and organization of the forestry staff.
- o Relationship of base forestry operations to total base operations and the degree of professional autonomy in forestry activities.

Two other changes are desirable, and are:

- o Restructuring of the planning/operation linkage.
- o Change in the contracting procedure to allow greater control and flexibility.

a. Base Forestry Financing

The forestry operations at Eglin are currently financed under procedures specified in DOD Instruction No. 7310.3, dated 9 January 1979. This Instruction establishes that receipts from the sale of forest products from the base are available to cover forestry operation costs with any surpluses of receipts over costs being transferred into the U.S. Treasury as miscellaneous receipts. No carryover between fiscal years is permitted. Present annual receipts at Eglin AFB are approximately $900,000 and expenditures are $700,000.

As the biomass production program becomes a major part of the cost of the base forestry operation and the material produced is used on base, rather than being sold, the financing method will no longer support the required forestry operation. A later section details the estimated cost of the program -- a cost which will be in addition to the continuing cost of financing the base's normal timber sale load. It is imperative that these additional costs be met, either by line item appropriation or by "offset" arrangement whereby base operating funds scheduled for fuel purchase are made available for biomass production.

b. Base Forestry Organization

It is believed that the continuation, or expansion, of the normal timber sale program at Eglin AFB is desirable. The nation's growing need for timber and fibre, plus the favorable impact on the local economy, argue for increasing intensive resource management of Eglin's forest land. The additional management responsibilities entailed in a biomass production program must be met by an expansion of the base forestry staff. The existing organization and essential restructuring are shown in Figure 9. The recommendations recognize the expected increase in the volume of timber to be sold, in the volume and complexity of the reforestation program, and especially, in the greatly expanded responsibilities generated by the proposed harvesting and transportation activities.

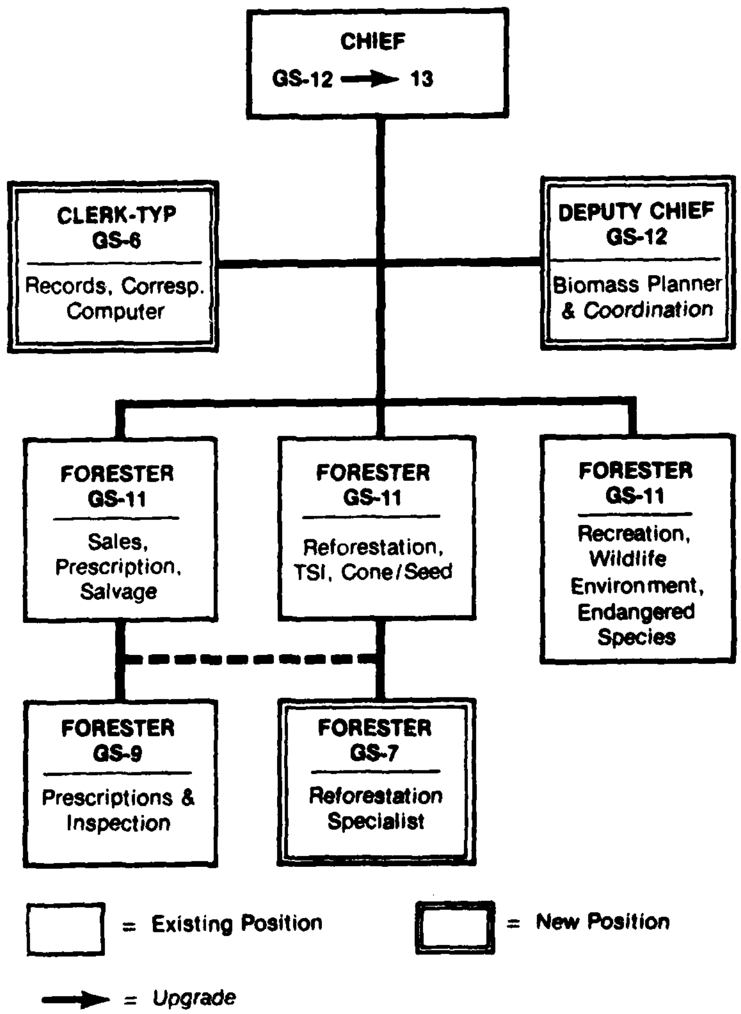

Figure 9. Existing and Proposed Forestry Staff, Eglin AFB

No formal workload or system analysis has been made of the Eglin AFB organization. The estimates of additional manpower needs are based on experience with planning and contract administration of work programs of comparable dimension and upon the present manpower/workload ratio applied to the project related workload.

c. Role of Base Forestry Operation

At this time base forestry operations are peripheral to the total base operation and to the military mission that it serves. With the initiation of the BEI concept, the forestry operation will become a vital part of the base's support system and its relative priority must increase significantly. Recognition of this shift and successful implementation of the program will require a new perception of forestry's role by the base decisionmakers. It is imperative that the base forestry staff be given full authority to operate within approved plans and policies. Periodic inspection by competent authority to ensure adherence to prescribed procedure is, of course, essential to any management program and such oversight activities should be continued.

d. Planning/Operation Linkage

The organization changes shown in Figure 9 are imperative. It is also desirable that the Air Force make an additional shift in organization. The existing Eglin AFB organization separates the planning and operation functions of the forestry effort as shown in Figure 10. In the proposed biomass production program, intensive use of technicians is expected in stand layout, day-to-day reforestation contract, cone collection administration, and the inspection of harvesting operations. At the same time, the normal forestry operations of timber marking, sale inspection, prescribed burning, and salvage marking will continue. The fragmentation of responsibility and the divorcing of planning and implementation is not appropriate to the silvicultural process and leads to lowered quality of resource management.

Silviculture is defined as the art (rather than the science) of producing and tending a forest and forest trees. It is not susceptible to quantification and specification in the same degree as are the engineering sciences. The transfer of silvicultural planning to the field requires a high degree of rapport between the professional and the technician. This needed understanding is not fostered by the existing organization.

The essential mutuality of goals and philosophy between planner and implementor is imperative. The existing organization does not appear to support the degree of interaction required. Therefore, it is recommended that the planning and implementation phases of the forestry operation be integrated as shown in Figure 11.

e. Flexibility in Contracting

The success of the proposed program will require a high level of coordination between the various components of the program. The research orientation of the project will require closer than normal adherence to contract specification and will require a contractor who can work closely with

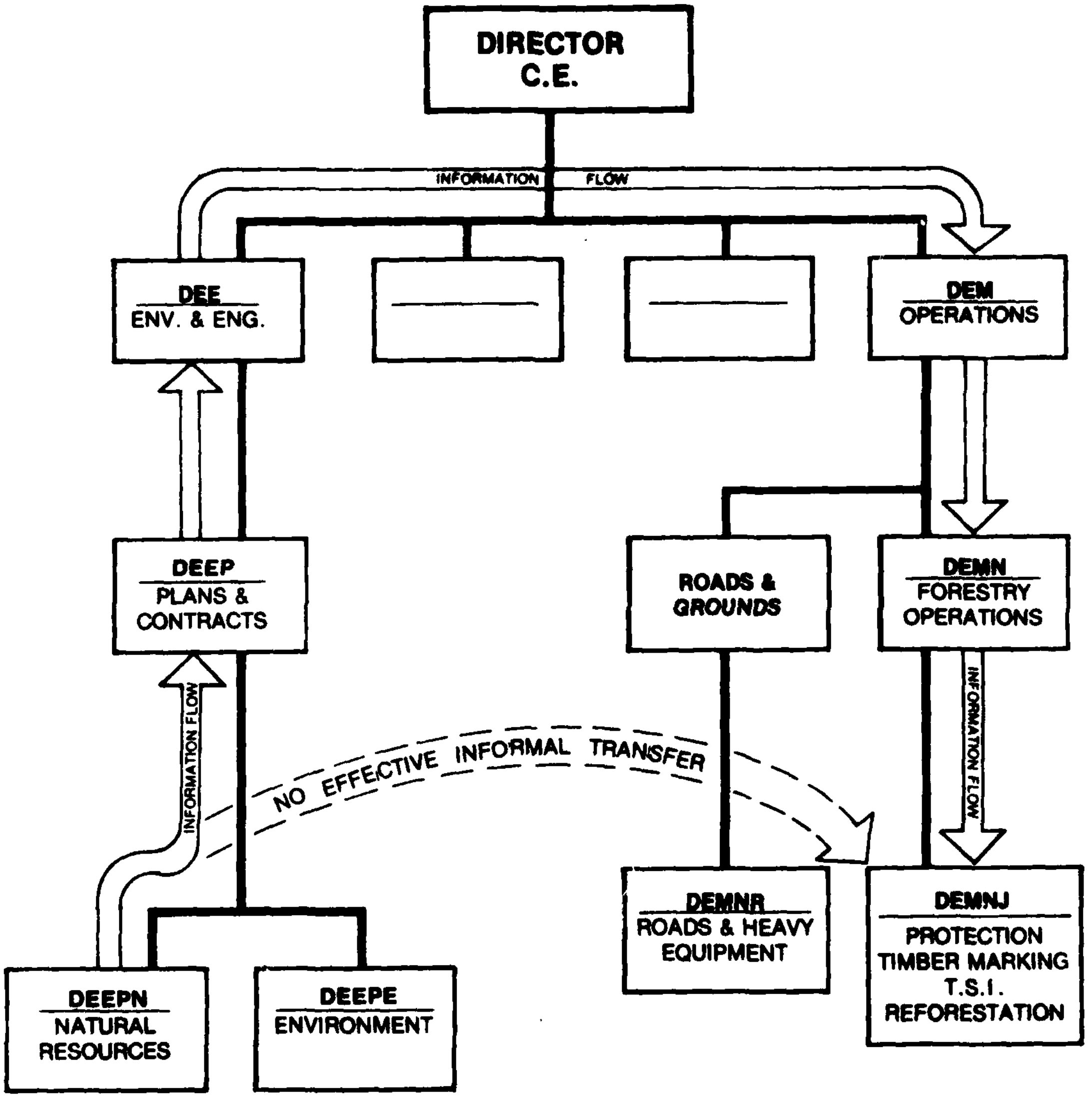

Figure 10. Existing Information Transfer Process - Silvicultural Planning to Implementation, Eglin AFB

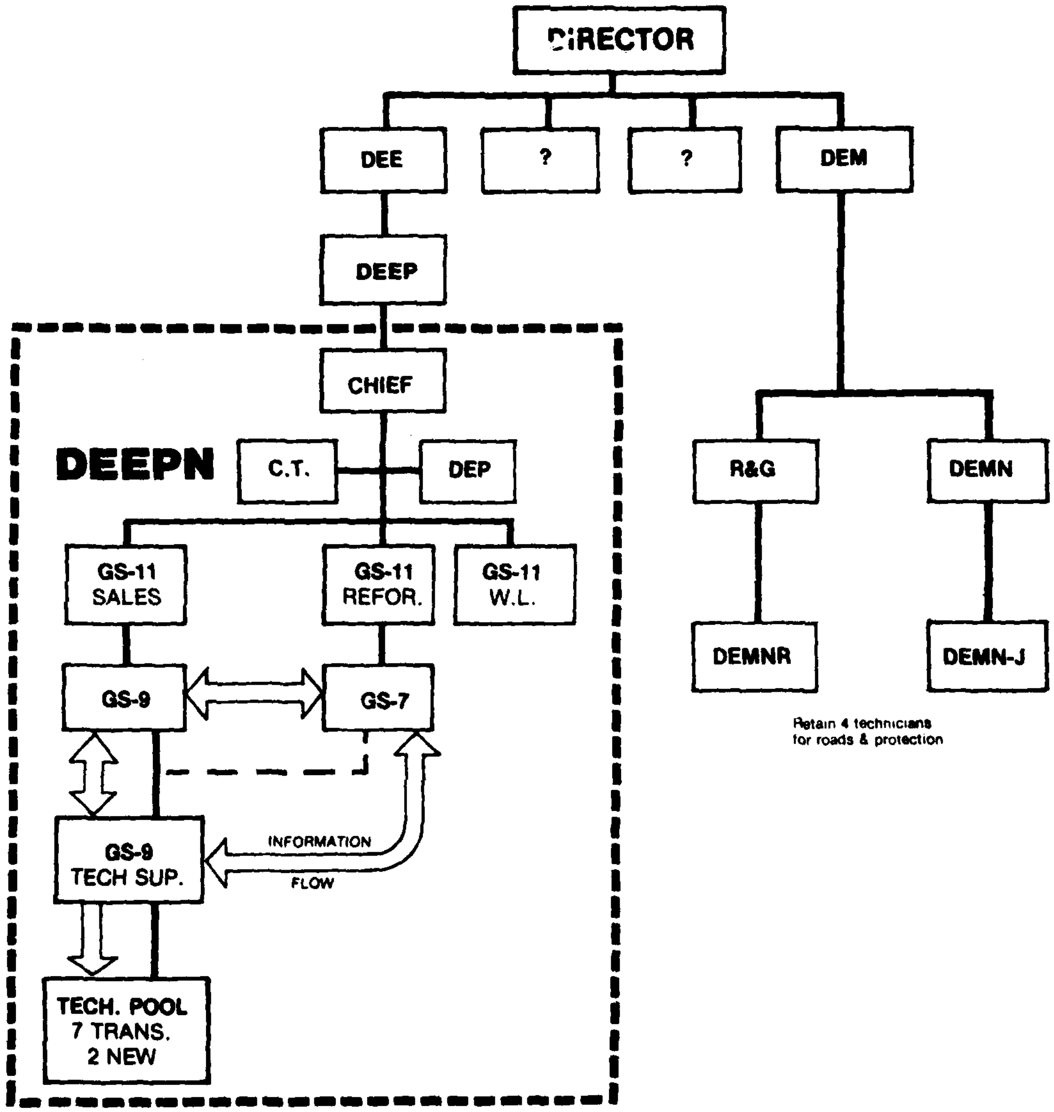

Figure 11. Proposed Organization and Silvicultural Planning to Implementation, Eglin AFB

those administering the contract. This coordination can be most easily achieved through a contracting system which permits maximum flexibility in this relationship. It is therefore recommended that contract solicitations and specifications emphasize the need for such flexibility and that the contract include a provision which will allow prompt termination of the contract should the administrator find that the contractor is unwilling or unable to respond to changing circumstances or to redeem his obligations fully under the contract terms.

SECTION VI

SUPPORT DETERMINATION

1. GENERAL

This section deals with the manpower support and cost considerations inherent in the implementation of the BEI concept at Eglin AFB and the management practices proposed in Section V. The impact of the implementation on the current forest management organization will be examined; and both capital costs and recurring costs will be reviewed.

2. MANPOWER

The manpower support needed to handle the biomass management concurrent with commercial sales and the other usual forestry activities is shown in Table 11.

The indicated total increase in the manpower level is from 17 to 22. The existing position of Chief will be upgraded from 12 to 13 and a new position, Deputy Chief, Grade 12, will be created. This will allow for overall management of the forestry staff and programs and accommodate a division of management between the current forestry functions and those entailed in the production of biomass fuel.

Currently, there are three Forester, Grade 11, positions allocated. Areas of responsibility can be categorized by sales/harvesting, reforestation and wildlife management and other environmental concerns. The existing Grade 9 Forester and a newly created slot for a Grade 7 Forester (a reforestation specialist) would be used in field reconnaissance and quality control. The proposed staffing discussed thus far represents an increase of two positions of professional classification.

Table 11 proposes three new nonprofessional positions for the forestry staff: two technicians and a clerk-typist.

Technicians are presently utilized by the forestry staff through the submission of work orders to DEMNV. This method could continue, but optimum utilization of time and manpower suggests transferring the GS-9 technician supervisor and 7 technician positions to the forestry staff. Four technicians will remain in the operations division.

The work of the proposed clerk-typist is currently handled by available personnel in a typing pool. The increased workload stemming from expansion in the duties of the forestry staff and the establishment of a computerized stand record keeping system argue for the creation of a new full-time clerical position on the forestry staff.

TABLE 11. EGLIN FORESTRY STAFFING AND SUPPORT EXPENSE

Title	Grade	Salary(1)	Existing		Proposed	
			No	$	No	$
Chief	13	$40,100	-0-		1	$ 40,100
Chief	12	33,700	1	$ 33,700	-0-	--
Deputy Chief	12	33,700	-0-		1	33,700
Forester	11	28,100	3	84,300	3	84,300
Forester	9	23,500	1	23,500	1	23,500
Forester	7	19,000	-0-		1	19,000
Technical Supervisor	9	23,500	1	23,500	1	23,500
Technician	5	15,400	11	169,400	13	200,200
Clerk-Typist	6	17,100	-0-		1	17,100
TOTAL			17	334,400[2]	22	441,400
Equipment Use, Materials, Supplies, Overhead [3]				250,800		331,000
				$585,200		$772,400 rounded to ($775,000)

[1] Step 3 salaries increased by 12% for retirement, life and health insurance, and sick.

[2] Not comparable to current budget figures which include only directly work-related hours.

[3] 75% of salary.

In summary, five new positions are proposed over and above current base manning levels: Grade 12, Deputy Chief; Grade 7, Forester; Grade 6, Clerk-Typist; and two Grade 5 Technicians. In addition, the position of Chief is upgraded from 12 to 13.

3. COSTS

The principal costs associated with the forestry and harvesting operations of the BEI concept are the annual recurring costs. The capital outlay costs are inconsequential because the proposed implementation mode calls for the contractor(s) to supply all of the necessary equipment. The manpower and administrative costs are shown in Table 11. The remaining costs will be incurred through contractual arrangements for the performance of stand

generation, chip harvesting and transportation. The component elements of these functions are examined below.

a. Site Preparation

It is anticipated, as discussed previously, that site preparation will be needed only for the first 2 years of the BEI project. The costs presented are current, 1982 contract pricing on Eglin AFB in Florida, and are for sites prepared with a Marden 11-ton duplex brush chopper.

Single chop - $27.00 per acre

Double chop - $52.00 per acre

Average cost expected - $35.00 per acre

b. Planting

No experience data is available for CSP biomass (close spacing) planting as planned for Eglin AFB. Current costs for standard spacing, 800 seedlings per acre, range from $18 to $30 per acre, excluding seedling cost. The estimated costs averaged from three sources for biomass planting, 2700 seedlings per acre, is $56.50 per acre excluding seedling costs. One-year old bare root seedlings cost $16 per thousand or $43.20 per biomass acre at Eglin AFB. This equates, as shown below, to a total per acre cost of $100.

Planting	- $56.50 per acre
Seedlings	- $43.20 per acre
@ $16/1000	
Total	- $99.70 per acre

c. Seeding

CSP seed varies in price but is currently averaging $55.00 per pound. The 1981 contract price for broadcast seeding 4,689 acres on the Ocala National Forest in Florida was $4.95 per acre. The next bid price on this contract was $5.00 per acre; this latter figure is used here. The broadcast seeding rate proposed is 1/4 pound of seed per acre. At this seeding rate and with the quoted price structure, broadcast seeding should cost $19.00 per acre at Eglin AFB.

Broadcast Seeding	- $ 5.00 per acre
Seed (.25 x $55)	- $13.75 per acre
Total	- $18.75 per acre

The costs of machine seeding, planting the seeds, is currently estimated at $30.00 per acre in northwest Florida. The seeding rate is reduced however to .2 pounds of seed per acre which places the per acre cost at approximately $41.00.

Direct Seeding	-	$30.00 per acre
Seed (.2 x $55)	-	$11.00 per acre
Total	-	$41.00 per acre

Utilizing the above pricing and the mix of regeneration methods discussed previously, the weighted average cost for regeneration at Eglin AFB is $64.00 per acre as shown in Table 12.

TABLE 12. WEIGHTED REGENERATION COST PER ACRE

Method	Percentage	Cost per Acre	Weighted Cost
Planting	50	$100	$50.00
Broadcast Seeding	30	$ 19	$ 5.70
Machine Seeding	20	$ 41	$ 8.20
Weighted Average Cost per Acre			$63.90

It should be stressed that this cost is expected to drop as regeneration shifts from planting and machine seeding to broadcast seeding. This will occur as the research and development requirements of planting and machine seeding decrease and seed supply increases from the changes in seed orchard size and cone management.

d. Chip Harvesting and Transportation

The cost of the wood chips is extremely variable. Contributing factors will include: contract duration, stand density, equipment type and technological level, efficiency of the operation and the competitiveness of the market place.

Estimated costs for energy chips delivered during the first 15-year period at Eglin, are based on a blend of recently quoted rates adjusted for stand densities and an estimated 10-mile haul. Areas with sparsest stands will be regenerated first, and the price for this wood will be higher than for stands harvested in the last half of the startup period. With contract rates adjusted for local conditions, these FOB-yard prices for the Eglin BEI are projected:

Mixed scrub-oak/longleaf/and natural sand
pine @ 15 tons/ac . . . . $14.00 FOB yard

Offsite slash pine @ 30 tons/ac . . . . $13.00 FOB yard

Planted sand pine @ 70-90 tons/ac . . . . $11.00 FOB yard

As of January 19, 1982, Morbark Industries, a leader in manufacturing whole-tree chippers, quoted a price of $8.53 per ton in a transportation van. This price excludes stumpage and transportation costs, and is the producer's cost, not the buyer's cost. Morbark's method of arriving at the $8.53 figure is considered valid because it reflects input from several operations in continuing operational production,rather than in a test condition.

The cost breakdown developed by Morbark is as follows:

Equipment Itemization and Cost

The equipment mix used with a typical whole-tree harvesting operation centered around the Morbark Model 20 Total Chiparvestor will vary from region to region and will also vary with the type of material harvested and the amount of production desired. Listed here is the equipment surrounding a typical Model 20 operation in the Lake States area to harvest low grade hardwood stands on rolling terrain with fairly good ground conditions.

Morbark Model 20 Total Chiparvestor		$127,500.00
One Mor-Bell Logger with Feller Buncher		$ 45,500.00
Two Units:	(1) Grapple Skidder	$ 75,000.00
	(1) Mor-Bell Logger	$ 39,500.00
Yard Tractor (with Blade)		$ 13,200.00
Maintenance and Fuel Truck		$ 11,000.00
	TOTAL Equipment Cost	$311,700.00

Using an average life of 5 years for the logging equipment in this operation, the equipment is fully depreciated over the 5-year period. It is realized that there will be considerable residual value left at the end of the 5-year period. There are, however, pieces of equipment included in the harvesting system which might be traded advantageously at the end of 3 years, rather than the following year. The residual value left at the end of the 5-year period will be more than enough to offset any additional cost of trading at any earlier time period.

The interest is calculated on a declining balance pay back at 18% over the 5-year life of the equipment.

The chipping operation is considered up and running for 200 days a year.

Original Equipment Cost.................................$311,700.00

Interest:	18% (simple interest declining balance) over a period of 5 years................................	$163,000.00
Insurance:	Insurance is figured on a replacement value. Thus, calculating $10 per $100 per year on the original cost of the harvesting equipment, insurance cost then would be................	$155,850.00
Maintenance:	Average maintenance escalating cost over a period of five years includes: maintenance, labor, engine oil lubrication and hydraulic oil, chipper knives, counter knives and miscellaneous supplies.	

1st year - $28,053	4th year - $ 46,755
2nd year - $31,170	5th year - $ 52,989
3rd year - $40,521	$199,488

TOTAL...........$830,038.00

Production: While production capacity has been experienced in excess of 300 tons per day on a sustained basis, for the purpose of this analysis, the conservative figure of 200 tons per day is used.

200 T/day x 200 day/yr = 40,000 T/yr. For 5 yrs (the depreciation period) = 200,000 T. Then $830,038 / 200,000 T =

COST PER TON....$ 4.15

Fuel: After reviewing fuel consumption figures from several operations, it is estimated that all operating equipment will consume about 160 gallons of diesel fuel per day. This does not include any diesel fuel consumption for the trucking to the operation. At an average of $1.25 per gallon, it would equal $200 per day x 200 days = $40,000 x 5 years = $200,000/day; x 200 days/yr = $40,000/yr; x 5 years = $200,000; / 200,000 tons =

COST PER TON....$ 1.00

Labor:	Five-man labor force averaging $600 per week per man, which would include direct and indirect costs including payroll, taxes, insurance, etc. = $3,000 per week.	
	$3,000 per week x 40 weeks per year = $120,000; x 5 years = $600,000; / 200,000 tons =	
	COST PER TON....$	3.00
Miscellaneous:	Miscellaneous expenses to include administrative costs, taxes, rental on office building, etc. $75,000 / 200,000 tons =	
	COST PER TON....$	.38
	MORBARK'S TOTAL COST PER TON IN A VAN....................$	8.53

To the foregoing cost experience, this study would have to add:

Transportation costs @ $.10 per ton mile x 10 miles (Reference 9)............$	1.00
Operator profit and risk margin @ 10%....................................$	.95
Estimated cost FOB-yard..................................$	10.48/ton

The calculated cost FOB-yard for high-volume plantation wood, therefore, is about $10.50, compared with the adjusted estimated cost of $11.00 per ton based on current contract rates.

4. SUMMARY OF SUPPORT COSTING

The projected activity and costing for the forestry operation to develop the BEI during the first 15 years of the project is summarized in Table 13. The sequence of events assumes Option 1 to be on line at the beginning of the 6th year and Option 2 to be on line at the beginning of the 7th year. The entire base system will be operational at the beginning of the 12th year.

TABLE 13. COST AND REVENUE SCHEDULE

Year of Operation	System On Line			Forestry Operation				Forestry Revenue	Wood Fuel	
				Salaries and Support ($000)	Contract Reforestation ($000)	Road Maintenance ($000)	Total ($000)		Available	Required
	1	2	3						Ton (10^3)	Ton (10^3)
1				600	480	--	1080	1150	70	--
2				600	480	--	1255	1300	85	--
3				775	450	--	1225	1450	100	--
4				775	450	--	1225	1450	100	--
5				775	450	35	1260	1450	100	50
6				775	450	35	1260	1450	100	100
7				775	450	35	1260	975	245	240
8				775	450	35	1260	975	245	240
9				775	450	35	1260	975	245	240
10				775	450	35	1260	975	245	240
11				775	450	35	1260	975	290	240
12				775	450	35	1260	885	290	540
13				775	450	35	1260	885	290	540
14				775	450	35	1260	885	290	540
15				775	450	35	1260	885	290	540
16				775	450	35	1260	885	540	540

NOTE: Costs and Revenues in 1982 dollars.

SECTION VII

INTEGRATION OF FINDINGS

1. BACKGROUND

To date, four studies have been conducted by the Air Force concerning four different aspects of biomass utilization as a facility energy source under a BEI concept. Each of these studies, from its point of view, has unconditionally supported the conclusion that Eglin AFB is an ideal candidate for a demonstration of the BEI concept. This section integrates the findings of this and the three previous studies, taking into account both research and development and operational needs.

2. TECHNICAL REQUIREMENTS AND APPROACH

The initial BEI study, after identifying Eglin AFB as the prime location for the concept implementation, explored the technical and then the economic feasibility of applying current and advanced biomass energy conversion technologies to the installation. In keeping with the research and development nature of the effort, two different technologies are proposed and in progressingly larger sized systems. The side-by-side placement of the two technologies, a gasification, combined cycle system, and a direct combustion, cogeneration system, permits the demonstration and direct comparison of separate methods of biomass conversion in full online operation.

Since the time when these systems were designed and sized, the Eglin AFB engineering department has undergone staff and management changes. The new management plans and updated consumption information have a bearing on the previously proposed energy conversion system plans. For these reasons it is suggested that a detailed review of the technological aspects of Eglin's adaptation to BEI status be conducted.

3. SILVICULTURE

To produce 540,000 green tons per year needed to fuel a base-wide operation, 98,800 net acres must be included in energy plantations. This acreage has been identified. It is almost equally divided between the Federal Aviation Administration air corridor for Okaloosa County Airport Forestry Management Compartments 2 and 4, and existing pine plantations throughout the base.

These areas will eventually be totally reforested in the selected species, Choctawhatchee sand pine, starting with the areas with the sparsest growth. Approximately 6,000 acres per year will be site prepared for planting or seeding by allowing local chip producers to clear out the sparse growth areas and keep the chips produced. This arrangement would continue until the chips are needed at Eglin AFB as fuel. At that time the chippers would be placed under contract for fuel harvesting. For research and development

purposes, these areas should be regenerated, on a contract basis, by planting seedlings (approximately 3,000 acres at an average of 2,700 seedlings per acre) by direct row seeding (approximately 1,200 acres with .20 pound seeds per acre), and by broadcast seeding (approximately 1,800 acres with .25 pounds of seed per acre). R&D emphasis will be on developing the best method for broadcast seeding, clearly the least costly.

The rotation period, the length of time between establishment of successive stands, will vary from stand to stand due to environmental differences in soil, water, amount of sunlight, and level of disturbance, etc. For the variety of sand pine selected for Eglin AFB, the age at which the average per acre production peaks is between the 10th and 15th year. This interval can be shortened if irrigation and fertilization practices are followed. However, due to the size of the areas involved, the cost of such programs would be prohibitive at Eglin AFB. The rotation period for Eglin should be established at 15 years, pending research in the continuing program.

The harvesting, or chipping, and transportation of the wood fuel, while not part of silviculture, is a vital segment of the BEI concept at Eglin AFB. To enhance productivity and lower costs, this phase of effort should be totally contracted. This operation, in order to supply the required quantities of wood fuel, will involve 7 to 9 chipping units in the field with the operation of associated support equipment and the transportation vehicles (tractors and vans) for the delivery of the chips from the field to the wood yard. The typical configuration for a single field operation at Eglin AFB will probably be composed of 1 chipper, 3 feller-bunchers, 2 skidders, 2 chip vans, 1 tractor and 1 maintenance pickup truck. This combination is expected to provide the chips at a cost of $10 to $14 per ton FOB the wood yard.

4. MANAGEMENT IMPACTS AND ECONOMICS

The recommended biomass energy conversion technology will occasion no major changes in the current engineering system at Eglin AFB. There should be no need to alter the current manpower staffing. However, there will be substantial changes in the functional duties of the staff. These functional changes will result from utilizing a solid fuel, as opposed to the current gas and liquid fuels, and should be handled by the engineering system with little difficulty.

There will be no economic impact attributable to engineering organization change stemming from the implementation of the biomass conversion system. However, the BEI establishment entails considerable capital costs in the range of $56 million for equipment (exclusive of the cost of the wood-fuel handling system and wood yard).

Another consideration is the potential for savings to be generated by the fuel price differential.

All these factors have been evaluated in terms of the system's anticipated economic efficiency, and all support an expectation of a favorable return.

The base forestry system, under the BEI concept, is affected much more than is the engineering system but this is to be expected. To carry out the necessary steps in providing wood fuel from biomass grown on the installation's forested lands the forestry system will require reorganization, increased staffing, and new forest management plans.

The reorganization, increased staffing, and new forest management plans are all direct results of the increased workload associated with the change in direction of managing the forest resources for fuel as opposed to marketable timber. Although all of the actual field work will be contracted, a great deal of effort will be needed in planning, contract administration and tracking the progress of the stands, etc.

The economics of the base forestry system under the BEI concept seem affected or not affected, depending upon the frame of reference. Holding to the statutory constraints of Public Law (10 USC 2665[d]), the regulatory constraints of DOD instruction 7310.5, and the available acreage identified in the previous study, a slightly unfavorable set of circumstances will prevail. Because of the need to utilize almost all of the 90,000 acres identified as biomass plantation, the commercial timber sales will decline as the areas are cleared and planted. This will cause a decline in forestry revenues and, in about the 6th year of the program, the silviculture and staff costs will exceed the revenues and will continue to do so for the remainder of the program. Under existing constraints, there are no funds that can be made available to pick up this shortfall. Figure 12 shows this situation graphically. The revenues predicted are based upon a minimal annual conventional timber sales program. Solutions to these problems are not difficult. First, additional base lands can be opened for timber sales on an as-needed basis. This will not only bring in more revenue but will provide the much needed forest management to these lands. Second, action can be taken to remove the statutory and regulatory constraints to allow flexibility in the use of forest resources. Neither of these actions appears to be faced with strong resistance; rather, it should be sufficient to present a well-documented and organized alternative along with a request for relief from the constraints. The best alternative would be the flexibility to apply timber sales revenues and/or O&M funding to the management expenses as required. The proper balance of funding should be predictable as the program progresses.

Under the current system, staff and regeneration costs remain about the same for the first 15-year period, after the slight increase at the time of initial buildup. Revenues from timber sales are expected to exceed costs for the first 6 years; then a decline in commercial timber sales will attend the shift in regeneration from scrub oak/longleaf to plantation CSP (Figure 12).

Figure 13 shows the availability of wood fuel, over time, as the biomass production approaches steady state in the fifteenth year. Phasing of construction and on-line operation can be judged from this progression. The harvesting costs, in practice, will be fuel costs and will be more than offset by reduction in electricity and natural gas use at steady state operation (15th year and beyond). This cost avoidance will be the annual

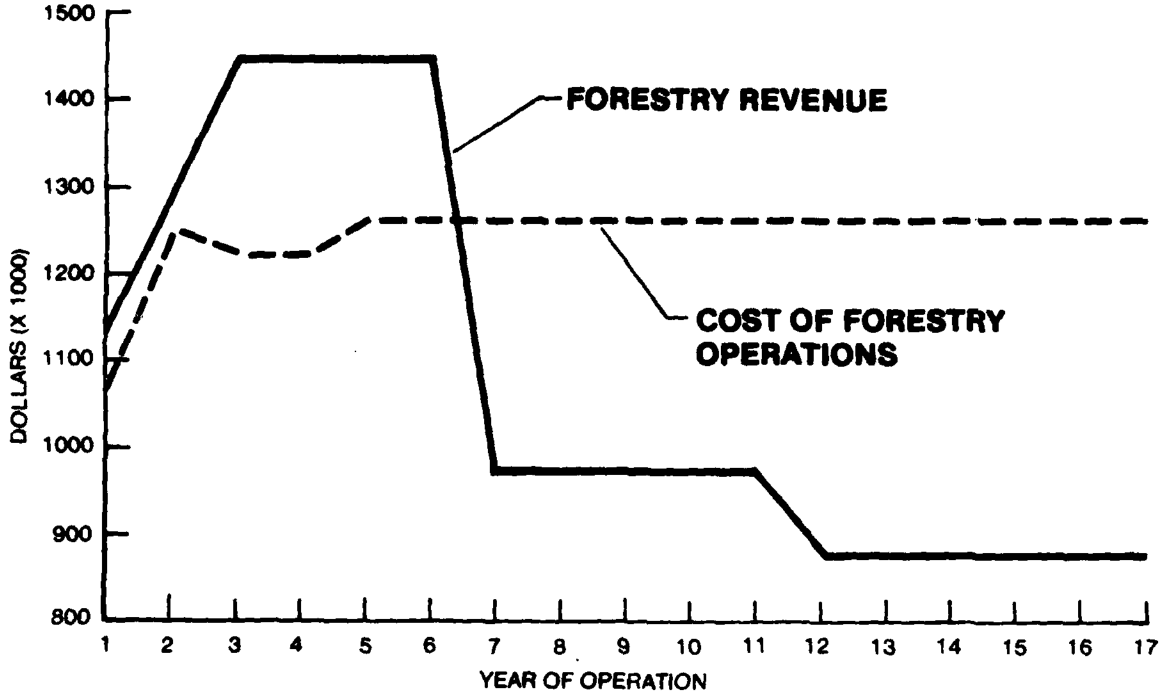

Figure 12. Timber Sales Revenues vs. Cost of Forestry Operations

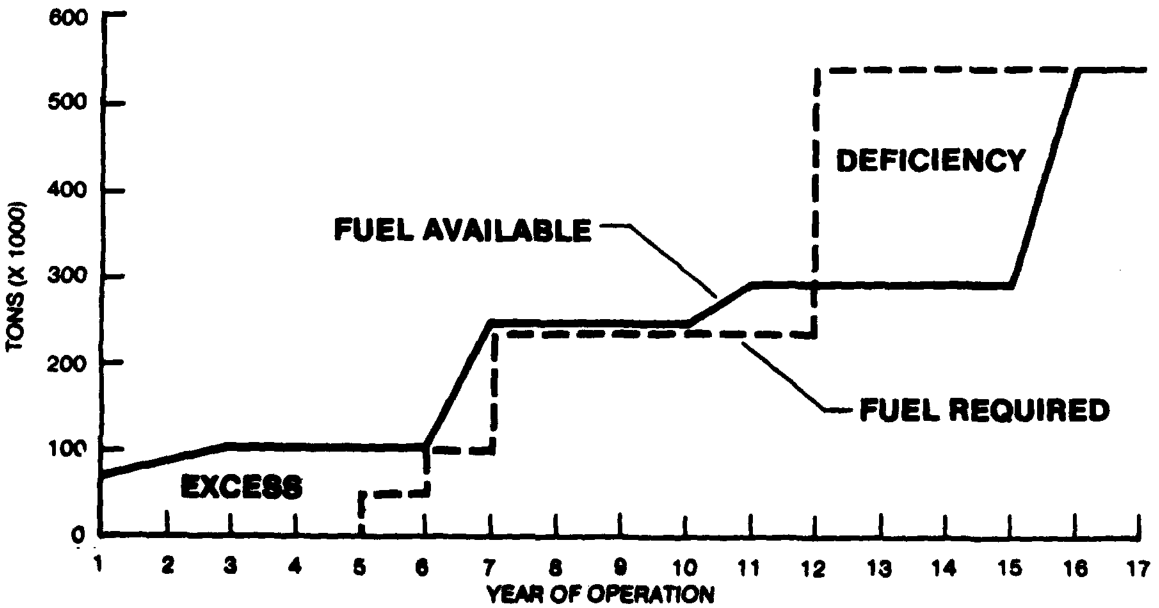

Figure 13. Wood Fuel Availability vs. Requirements

difference between $14 million per year for electrical and natural gas (1981 cost) and $6-$8 million for chips ($12-$15/ton), which amounts to between $8 million and $6 million per year.

Initially (year 1 through year 4), until a using system comes on line, chips will be produced as marginal land is cleared for planting. These chips can be sold for revenue and/or stockpiled for use. The chip production from the 4th year on is a function of both requirement and state of development of the forested lands. The estimated production capability is also shown in Figure 13. If the total BEI is implemented before the 15th year, a production deficiency may be seen.

Wood-chip shortfall anticipated in years 12 through 15 of the Eglin BEI project is predicated on the implementation of the concept in the shortest possible time. The shortfall can be overcome in one of three ways:

a. Implement only the main base module of the project during the first 15-year period. Defer the whole-base implementation until the biomass plantings come on line starting in year 16.

b. Purchase chips from offbase sources to eliminate the shortfall during the final 4 years of the first 15-year period.

c. Designate harvesting sites on base that are outside of the designated energy plantation during the shortfall period.

It is suggested that this decision be deferred until year 5 of the implemented project. At that time, the main base will go on line, and the study/design phase of the whole-base extension will be about 1 year from inception.

Ascribing the proper proportion of total costs to fuel-wood costs, is illustrative of the total project cost impact. Table 14 summarizes the wood per-ton cost with the BEI in a fully staffed production mode.

TABLE 14. WOOD COST BREAKDOWN PER TON

Delivered chip cost	$10.48
Regeneration cost (no site preparation: weighted average cost of planting/seeding)	.71
Energy-wood portion of staff/support cost (estimated @ 70% of total costs)	1.00
Total	$12.19

This total fuel-wood cost compares favorably with oil and natural gas, in relation to the cost of a million Btu of produced energy (Table 15), when the following formula is applied:

$$\$ \text{ Cost/MMBtu} = \frac{\text{Cost per unit}}{\frac{\text{Heating factor}}{10^6} \times \text{Combustion efficiency}}$$

Table 15. Comparative Cost per Million Btu

	Cost per Unit	Heating Factor (Btu/Unit)	Assumed Combustion Efficiency	Calculated $/MMBtu
No. 6 Oil	28.00 bbl	6.29×10^6	.86	5.17
Natural Gas	3.55 MCF	1.03×10^6	.90	3.83
Wood Chips (CSP 50% moisture content)	12.20 Ton	8.6×10^6	.67	2.12

In summary, the use of Air Force-grown woody biomass to supply the total energy needs of Eglin AFB is feasible from both the forestry and the engineering standpoint. Such a program would make Eglin energy self-sufficient, and would simultaneously save substantial defense dollars. Concurrently, the program would increase the productivity of public lands now producing at a small fraction of their capability. Application of the BEI concept to Eglin AFB will not only enhance our national defense capability, but will represent both good business and sound resource management.

SECTION VIII

AREAS FOR FURTHER INVESTIGATION

1. GENERAL

Energy biomass silviculture is an emerging field in which knowledge is still limited. This BEI program will present a unique opportunity to help close these gaps in knowledge. This section of the report identifies areas of needed information which, when fully developed, will have the critical impact on the implementation of the biomass plantation concept. This section also recommends action to help develop this crucial missing knowledge. Further, this section also identifies planning or policy actions which must be considered to allow effective implementation of this concept.

Some of these actions should be taken before implementation begins; others can be a part of the ongoing activity and will shape the "steady-state" condition of the project. While some of the planning actions have been previously mentioned, they have been included here to afford a complete agenda for action.

2. PREPARE AN ENVIRONMENTAL IMPACT STATEMENT

It is strongly recommended that the Air Force prepare an Environmental Impact Statement covering the proposed action in accordance with Section 102(2) (c) of Public Law 91-190.The dedication of some 90,000 acres to the production of energy biomass is an unprecedented federal activity with significant implication for the future management of other federal lands. It will be the object of intense scrutiny from professional and environmental groups. By any standard, it is a major federal action significantly affecting the quality of the human environment.

3. DEVELOP AND FIELD TEST RESOURCE COORDINATION STANDARDS

It is recommended that the resource coordination standards and policies outlined in the 1974 Eglin AFB Comprehensive Natural Resource Plan be revised, expanded, and specified to the planned project. The revised standards would cover all phases of coordination considering stand size, configuration and spatial-temporal distribution based on wildlife, recreational, rare and endangered species, visual, cultural, soil, and water resource needs. The standards should be prepared in consultation with concerned agencies and organizations. Revised coordination standards, field-tested on selected compartments, will form a solid basis for the silvicultural prescriptions which will be used to direct development activities.

4. DEVELOP A PUBLIC INFORMATION PLAN

It is recommended that the Air Force develop and implement a Public Information Plan to ensure that the energy biomass project is understood by

concerned groups and individuals. Energy farming will be a highly visible and controversial new forest management activity on the base. Locally, energy farming will affect hunters, forest industries, local governments, forest recreation users, environmental groups, and the Gulf Power Company. It will be of considerable concern to local congressional representatives, as well as a matter of regional and national interest.

5. SECURE UPDATED AERIAL PHOTOGRAPHIC COVERAGE SPECIFIED TO FORESTRY USE

We recommend that the Air Force secure current color aerial photography of a quality appropriate to the intensive level of resource management which will be required for this project. The base forestry staff currently uses black and white ASCS photography designed for measurement of farm allotments, agricultural use, etc. While usable for forest management purposes, they are not considered optimum.

6. PREPARE CONE PRODUCTION MANAGEMENT PLAN

A Cone Production Plan is an essential early step in the energy wood program. Such a plan should discuss cone management in both natural stands and in seed orchards of improved genetic stock. It should identify acreages needed and available, recommend cultural methods to increase cone production (thinning, fertilization, etc.) collection, extraction and storage methods, and discuss all other aspects of a cone management program.

7. COMPLETE SOIL MAPPING

Soil mapping is completed in Santa Rosa County and is underway in Walton County. About 50,000 acres of unmapped sandhill soils, all in Okaloosa County, lie within Eglin AFB Forestry Compartments 2 and 4 and the areas designated as "Possible Alternate Areas." This 50,000 acres should be soil-mapped at an early date to allow entry for prescription. It is suggested that the Air Force request the Soil Conservation Service to map these areas on a reimbursement basis.

8. PREPARE ENERGY WOOD MANAGEMENT PLAN (AND IMPLEMENTING PRESCRIPTIONS)

The forest management on the 90,000 net acres dedicated to the production of energy wood will be totally different from that specified in the existing Forest Management Plan. It is recommended that the Air Force prepare an energy wood management plan covering these acres and ancillary areas needed for coordination. Such a plan could incorporate the findings and recommendations in this and other related research studies. It would include land and forest description, objectives, silviculture, regulation and estimated yield, forest development needs and policies, together with a description of the prescribed control records. Prescriptions for individual compartments will translate this broad plan, together with the coordination standards, into on-the-ground stand design and treatment. Prescriptions can be scheduled in the plan and done before beginning activity in each compartment.

9. REVISE FOREST MANAGEMENT PLAN

Timber management on that part of the base not dedicated to energy production will remain essentially unchanged, but acreages, volumes, regeneration rates, and allowable cut will be reduced. The existing Forest Management plan (TAB B in the Eglin AFB Comprehensive Natural Resources Plan) should be revised to reflect these changes.

10. SILVICULTURAL AND ENVIRONMENTAL INFORMATION NEEDS

The silvicultural practices prescribed in Section III are based on presently available information. The School of Forest Resources and Conservation, University of Florida, the U.S. Forest Service, Southeastern Forest Experiment Station, and other public and private forestry agencies are presently considering an expansion of research efforts in a cooperative project entitled Biomass Production of Sand Pine Planted on Scrub Oak Sites in the Southeastern United States. The draft abstract for this project follows.

ABSTRACT

The productivity of sand pine in small research studies has been good, but the yields in operational plantings are not well documented and the impacts of intensive biomass harvesting and shortened rotations are largely unknown. Detailed sampling, including plantations established within and outside of the natural range of the species and representing a variety of stand factors, is required to quantify aboveground biomass, nutrient, and energy values. Comparative assessments of the nutrient pools of the natural oak forests and sand pine plantations are necessary to gauge the impacts of intensive forestry practices on these poor sites.

Results of this research will be integrated with ongoing studies being conducted by the University of Florida, the U.S. Forest Service, and forest industries to provide guidelines for management alternatives for the "sandhills" in the southeastern United States.

Because this research project will directly address many of the unanswered questions raised by the BEI concept at Eglin AFB, it is most appropriate that the Air Force expand its role as cooperator. It is recommended that the Air Force assist in the funding of this research effort and increase its participation to ensure that problem aspects pertinent to Eglin AFB are fully considered. These aspects would include:

1. Cost/energy efficiency and reliability of seeding versus planting of sand pine.

2. Cost/energy efficiency of site preparation on chipped lands.

3. Testing of the dual species concept described on page 17 of the Technical Report Biomass Energy Self-Sufficiency Resource Alternatives at Eglin Air Force Base, Florida.

It is also recommended that the Air Force become a cooperator in the Cooperative Research in Forest Fertilization (CRIFF) program which is sponsored by the University of Florida and the U.S. Forest Service. This program is aimed specifically at the problem of site productivity maintenance and enhancement, but has thus far concentrated almost exclusively on slash pine sites in Florida. Air Force participation would encourage the CRIFF program to consider the need for fertilization on sandhill lands.

Research into the project's effects on wildlife and endangered species should be part of the ongoing assessment. It is recommended that the Air Force explore the possibility of entering in cooperative agreements with the Florida Game and Fresh Water Fish Commission and U.S. Fish and Wildlife Service to monitor these effects and develop long-term policies relating to deer herd management and red-cockaded woodpecker management on Eglin AFB lands as related to energy wood production.

At some future time, the Air Force may wish to explore the potential of the other two possible options, Low Energy Subsidy, single species modified management; and High Energy Subsidy, sewage effluent application, which were considered in previous studies. It is suggested that action on this be deferred until the energy wood program is well established, at least until the end of the first 10-year period.

11. FOREST TREE NURSERY AND SEED FACILITIES NEEDS

At some point, the Air Force must consider the need for and the feasibility of establishing a forest tree nursery and a seed extraction and storage facility at Eglin AFB. It is recommended that this be deferred until seedling and seed needs are established by experience.

SECTION IX

CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS

This study has identified the silvicultural practices which can best provide wood fuels for Eglin AFB as a Biomass Energy Island utilizing energy plantations of the Choctawhatchee sand pine. These practices are cost effective and will produce that quantity of wood fuel necessary to satisfy all Eglin AFB energy requirements currently foreseen. BEI status can be achieved without adverse effect upon the base, its mission, its environment, or its relationship with the surrounding community.

The impact of the proposed silvicultural practices on Eglin's management and support will be minimal, and will be absorbed by the base forestry system. The cost of this impact, directly related to wood fuel regeneration and procurement, will literally be incorporated into the base fuel cost structure.

The technology of the biomass conversion systems is sound. Initially, both gasification and direct combustion cogeneration systems should be utilized for comparison purposes in the light of changing requirements for steam and electricity. The necessary wood fuels are obtainable. The phased implementation of the BEI concept is economically and technically feasible and desirable.

2. RECOMMENDATIONS

The concept of Eglin AFB as a BEI is both sound and timely. Given general concurrence in this conclusion, the following phased steps toward implementation are recommended:

a. The forestry department should begin implementing its part of the program. Regeneration of CSP should be started in the proposed energy plantation acreage. Additionally, the size of the CSP seed orchard should be increased if anticipated demands for regeneration are to be met.

b. A review of the technological aspects of Eglin's establishment as a BEI should be undertaken. Feasible changes in base energy consumption levels must be considered, and their relative consumptions correlated with conversion system design possibilities. In this way, the technology and the economics of the system(s) to be employed at Eglin can be more precisely formulated and optimal flexibility incorporated into the facility eventually envisaged.

c. Finally, an in-depth conceptual design of the energy conversion systems should be initiated. This step should be sufficiently comprehensive and the design so detailed in its integration of technology, operational requirements and the Air Force's commitment to the BEI concept that it could constitute a guide for the development of construction contract specifications.

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